REPORT REGARDING EVALUATION OF IRRIGATION DIVERSION RATES

In Re SRBA
Twin Falls County Civil Case No. 39576
Sub-Case No.: 00-00000

Report to the SRBA District Court

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INTRODUCTION

The purpose of this report is to document the methodology used by the Idaho Department of Water Resources (IDWR) for recommending irrigation diversion rates greater than 0.02 cfs per acre. This methodology incorporates both technical procedures and policies to establish the extent of beneficial use of water for irrigation by determining amounts reasonably necessary using acceptable irrigation practices. The development of this methodology included consideration of alternatives with regard to varying conditions and practices commonly found within the Snake River Basin in Idaho. It is anticipated that this methodology will be used for all present and future recommendations of irrigation diversion rates unless changes are warranted due to further improvements in analytical techniques or changing conditions.

OVERVIEW OF METHODOLOGY

Idaho Code §42-220 states that "... when water is used for irrigation, no ... license or decree of the court allotting such water shall be issued confirming the right to the use of more than one second foot of water for each fifty (50) acres of land [0.02 cfs per acre] so irrigated, unless it can be shown to the satisfaction of the department of water resources in granting such license, and to the court in making such decree, that a greater amount is necessary ..." The necessity of a greater amount can be difficult to determine. On one hand, the use of modern irrigation technology would ensure that an amount greater than 0.02 cfs per acre would rarely be necessary; on the other hand, many historical systems still in use today require an amount greater than 0.02 cfs per acre to maintain present production capabilities. In order to determine the necessity of a given irrigation diversion rate, crop water needs and water application and conveyance methods must be evaluated.

Hubble Report

IDWR contracted with Hubble Engineering, Inc. and Associated Earth Sciences, Inc. in July, 1990 to develop guidelines for evaluating irrigation diversion rates. The guidelines developed were completed in 1991 as two reports entitled, "Guidelines for the Evaluation of Irrigation Diversion Rates" and "Evaluation Workbook for Irrigation Diversion Rates." The first report (guidelines) provides background material, documentation, and an expanded explanation of the procedures including alternatives where possible. The second report (workbook) provides a systematic process for evaluation. These reports are collectively referred to as the "Hubble report." As guidelines, they are intended to inform IDWR personnel of the considerations involved in evaluating irrigation diversion rates and to guide them in making recommendations that are consistent and accurate. Copies of the Hubble report are included with this report for reference.

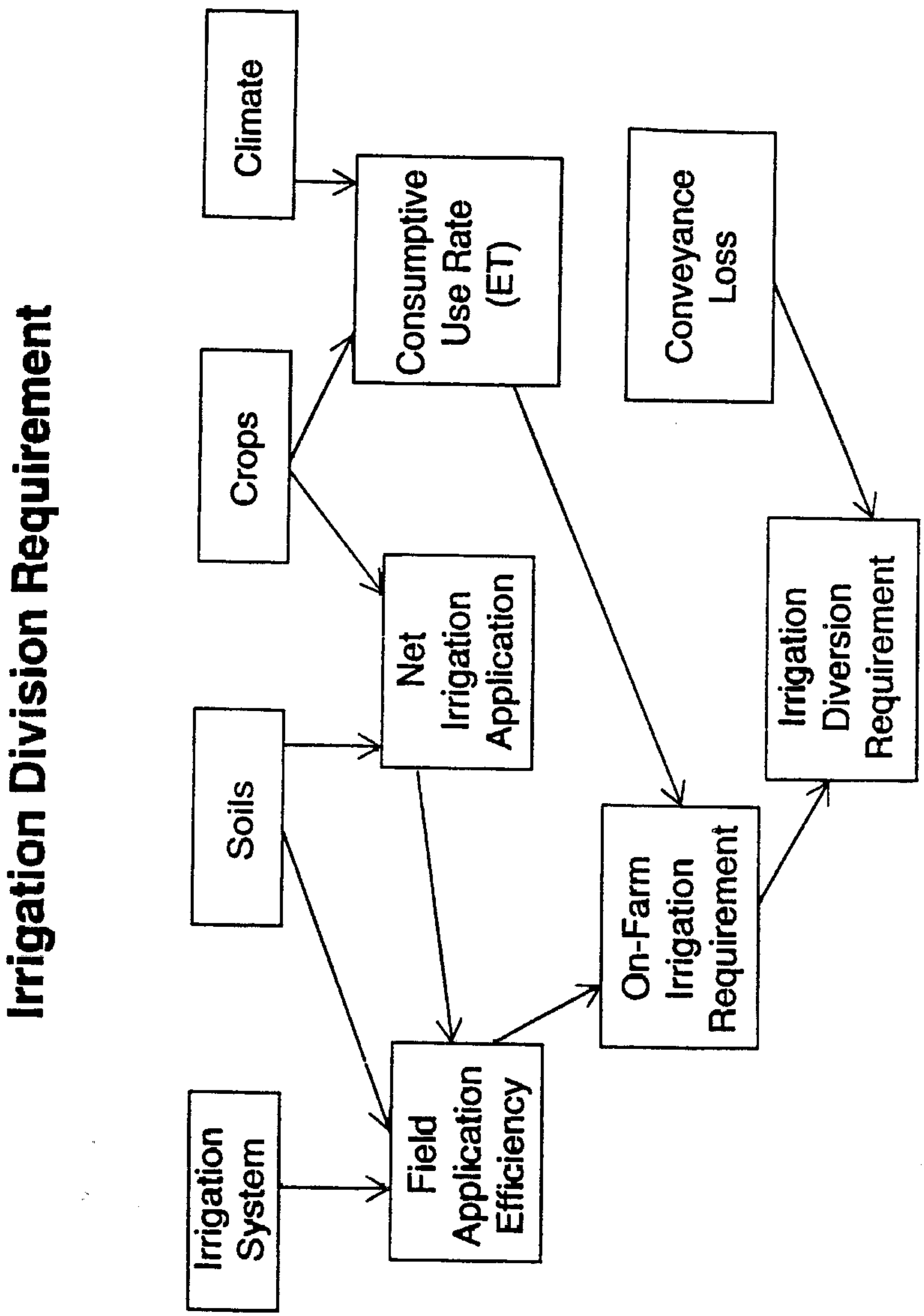
The Hubble report is based on widely accepted methodologies developed primarily by the U.S. Soil Conservation Service (SCS), now known as the Natural Resources Conservation Service (NRCS). In a 1994 report to the Hagerman Water Right Owners Association (HWRO), the University of Idaho found that, in general, "the report is well done", that IDWR's procedure is "... a sound engineering method", and that certain "... methods described are widely accepted" (Hazen, Gibson, and Neibling, p. 8). A copy of the University of Idaho report is included with this report for reference. The University of Idaho report also outlined some specific concerns which will be discussed later in this report. Some refinements have been made to the original methodology to improve or clarify the procedure; these will also be discussed later in this report.

It should be noted that the procedure outlined in the Hubble report is not the only way to evaluate irrigation diversion requirements. In fact, within the report itself there are several alternatives suggested for individual steps to allow flexibility depending on the availability of data. It is also important to note that the Hubble report does not provide judgements concerning the reasonableness of a particular diversion rate. It provides information about specific irrigation practices and conditions so that the necessity of a particular diversion rate can be determined based on reasonable policy decisions.

The basic methodology used to determine an irrigation diversion rate includes an assessment of crop water needs, irrigation system application losses, and conveyance losses from the source of water to the farm.[1] Figure 1 shows a simple flow chart presenting the basic data needs and sequence of calculations and estimations required. Climatic data and crop characteristics are used to estimate crop water requirements (consumptive use rate). Soil and crop characteristics are used to estimate the amount of water to apply during an irrigation (net irrigation application). The net irrigation application is then used along with information about the irrigation system to estimate losses during application of water to the fields. The net irrigation application is added to the application losses to estimate the diversion requirements for each field (field irrigation requirement). Lastly, the sum of the field requirements (on-farm irrigation requirement) are added to the conveyance losses to determine the total irrigation diversion requirement.

[1]The glossary found on pages 59-62 of the Hubble report guidelines may be useful to define many of the terms used in this report.

Figure 1



Irrigation Division Requirement
Climate
Crops
Soils
Irrigation System
Consumptive Use Rate (ET)
Net Irrigation Application
Field Application Efficiency
On-Farm Irrigation Requirement
Conveyance Loss
Irrigation Diversion Requirement

REPORT REGARDING EVALUATION OF IRRIGATION DIVERSION RATES

This report describes the evaluation of an irrigation diversion rate by initially focusing on the field requirements. Each of the elements necessary to determine the field irrigation requirements will be explained, in detail, in the next several sections of this report. The remaining sections will describe the determination of the on-farm irrigation requirement and conveyance losses in order to obtain the total irrigation diversion rate necessary at the point of diversion from the source.

Field Irrigation Requirements

The diversion rate necessary at the field is dependent on the water needs of the crop and the methods used to apply water to the field. The field irrigation requirement is estimated through use of the following equation:[2]

$$FIR = 4.2 \times (CU/FAE)$$

where:

FIR	=	field irrigation requirement in cfs/ac
CU	=	crop consumptive use rate in in/day
FAE	=	field application efficiency in percent
4.2	=	factor to convert units

This equation estimates the diversion rate required per acre at the field based on continuous use of the water.

EVAPOTRANSPIRATION (CROP CONSUMPTIVE USE)

Evapotranspiration (ET) is the "rate of water loss through transpiration from vegetation plus evaporation from the soil" (Hubble Engineering and Assoc. Earth Sciences, 1991b, p. 59). In other words, it is the amount of water consumed by a crop and evaporated from the surrounding soil during crop growth. For all practical purposes, evapotranspiration and crop consumptive use are the same. This water requirement is supplied by irrigation, precipitation, and soil moisture carryover from the non-irrigation season.[3]

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[2]The equation shown uses slightly different nomenclature than that shown on page 31 of the Hubble report guidelines. The reason for this is to clarify that the on-farm irrigation requirement is determined by adding the requirements for the individual fields that make up a farm. The field irrigation requirements are estimated individually because of varying crops, soils, and system constraints.

[3]For short intervals during the peak water-use period, precipitation and soil moisture carryover will be considered negligible in most cases. It is assumed that irrigation water will supply the entire ET requirements.

The ET rate depends primarily on the local climate, the crop type, the stage of growth of the crop, the condition or health of the crop and the availability of water. Figure 2 is a simple illustration representing crop ET curves for various crops. The ET curves represent the amount of water used during a growing season for each crop type. It can be seen from the figure that a crop will use different amounts of water at various times throughout the growing season. "Most crops have a higher consumptive use rate during certain stages of growth and for a relatively short time period. This is perhaps the most critical factor in the sizing of distribution systems" (Hagan, Haise, and Edminster, 1967, p. 775).

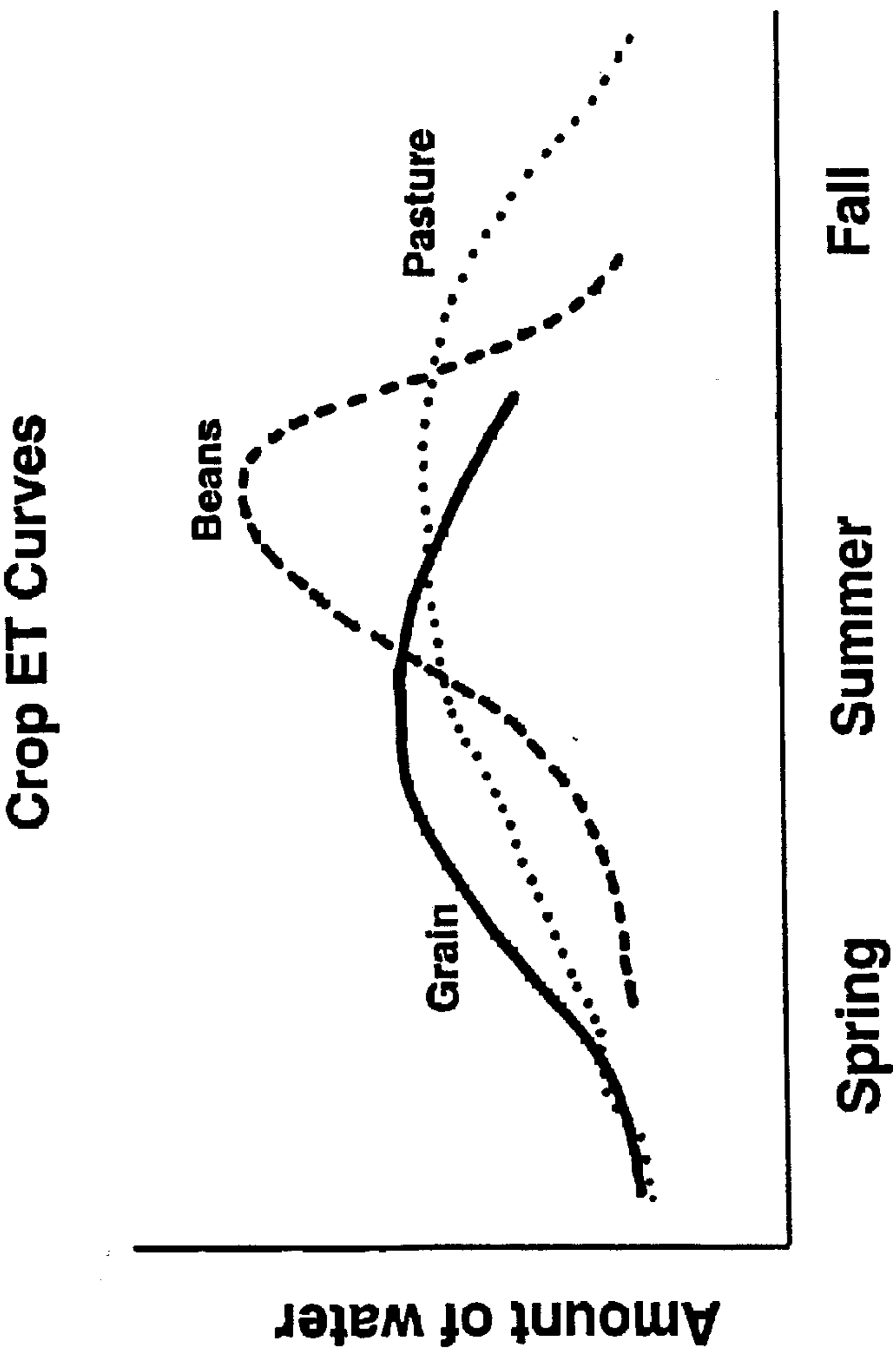
ET Estimation

ET is not normally measured directly for irrigation system design or management. This is due to the complexity and cost of measurement techniques. Direct measurements have been used in the development and calibration of equations used to predict ET. Numerous equations have been developed to estimate ET from climatic data such as air temperature, solar radiation, humidity, and wind. Selection of an appropriate equation depends on the intended use of the estimates and the availability of climatic data. In a 1983 report to IDWR, Allen and Brockway reported that "the FAO-modified Blaney-Criddle (FAO-BC) method was selected as the best method for estimating consumptive use on a statewide basis, based on accuracy and responsivness [*sic*] of the equation and the primary data requirement of air temperature, only" (Allen and Brockway, 1983, p. 78). Monthly ET estimates were calculated for 98 National Oceanic and Atmospheric Administration (NOAA) sites in Idaho based on 12 or more years of climatic data for each location. These estimates were presented as Appendix E (unpublished) of the Allen and Brockway report and are available at IDWR (see Appendix A for sample data). The Hubble report recommends use of these data for the evaluation of irrigation diversion rates.

Peak Period ET

The University of Idaho report to HWRO identified a concern in the Hubble report regarding the use of Allen and Brockway monthly ET estimates instead of estimates over a shorter period of time. This report stated that "because the [Allen and Brockway] report lists total consumptive water [use] by month, based on average monthly temperatures, it does not represent accurately the high demand that can exist for a short period of time" (Hazen, Gibson, and Neibling, 1994, p. 10).

Figure 2


Crop ET Curves
Beans
Pasture
Grain
Spring
Summer
Fall
Amount of water

The design capacity of an irrigation system is generally based on the peak ET of the cropping pattern for the period between irrigations (Jensen, 1983, p. 224). Unfortunately, short-term estimates of ET do not exist on a statewide basis.[4] In response to this concern, IDWR reviewed methods to estimate peak period ET from the Allen and Brockway monthly ET estimates. One method, developed by NRCS, uses an empirical equation to estimate peak period ET. Another method, recommended by the Food and Agriculture Organization (FAO) of the United Nations, uses a simple graphical procedure (Jensen, 1983, pp. 222-223). These methods account for the period between irrigations by considering the depth of irrigation water applied. The second method (FAO method) was adopted by IDWR because it also considers climatic conditions (see Adjudication Memo #42 attached in Appendix B).[5] Appendix C presents a comparison of this method to actual short-term ET estimates based on Agrimet[6] climatic data for Twin Falls, Idaho.

To use the FAO method, the Allen and Brockway monthly ET estimate (labeled "AVE ET", see Appendix A sample) is multiplied by a ratio which represents the peak period ET divided by the monthly ET. The appropriate ratio is dependent on the net irrigation application. The net irrigation application will be discussed later in this report. The Allen and Brockway monthly ET estimate should be used instead of the monthly consumptive irrigation requirement estimates (labeled "AVE IR", see Appendix A sample) called for in Adjudication Memo #42 (Appendix B). The Allen and Brockway consumptive irrigation requirement estimates represent the depth of irrigation water necessary to meet crop ET requirements, exclusive of precipitation. Rainfall is not relied on in arid areas to determine irrigation diversion requirements for short intervals during the peak water-use period.

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[4]IDWR currently has a contract with the Idaho Water Resources Research Institute to update the Allen and Brockway ET estimates statewide. The update will incorporate climatic data available since the original report was completed. The update will also include ET estimates for shorter periods in order to account for higher demands during those periods. Also, the update will include probability distributions for the estimates to allow for an assessment of the risk or confidence level associated with the estimates. IDWR anticipates adopting the updated estimates upon completion for use in evaluating irrigation diversion rates.

[5]Short-term estimates of ET could be calculated based on the statistical outputs included with the Allen and Brockway monthly ET estimates. This would require adjustment to the standard deviations of ET estimates to account for the use of long-term secondary weather parameters in the estimates (Allen and Brockway, 1983, pp. 16-18, 79-81). This method was not adopted because it does not provide a means to vary the period between irrigations.

[6]AgriMet is the Northwest Cooperative Agricultural Weather Network, a satellite-based network of automatic agricultural weather stations that provides data support for irrigation management and scheduling programs. Daily ET estimates, based on the 1982 Kimberly-Penman equation, are available for several locations in Idaho.

Peak Period Alfalfa Hay ET

Use of the Allen and Brockway monthly ET estimates to determine peak period alfalfa hay ET estimates requires use of the reference ET[7] values rather than the alfalfa hay values. The Allen and Brockway monthly alfalfa hay ET estimates are based on a mean alfalfa hay ET curve which smoothes the effects of cuttings over the entire growing season (see Figure 3); this is to account for variable harvest dates during the growing season (Allen and Brockway, 1983, p. 69). The smoothed curves do not represent the actual ET distributions when cuttings are considered. The actual ET values may be higher or lower than the smoothed values depending on the timing of harvests. During the peak water-use period, water requirements for alfalfa hay are better represented by the reference ET estimates.[8] The Allen and Brockway report shows that the ET for a second cutting of alfalfa hay (peak water-use period) will reach the same level as the alfalfa reference (Allen and Brockway, 1983, pp. 64 and 71). To estimate the peak period ET for alfalfa hay, the FAO method recommended above is applied to the Allen and Brockway monthly reference ET values.

Cropping Pattern

Most farmers practice crop rotation for a variety of reasons. The cropping pattern in any given year will have an effect on the irrigation diversion rate required. Referring back to Figure 2, it can be seen that some crops, such as pasture, have a relatively long growing season and will use water for a long period of time. Others, such as beans, have a shorter season but a higher water use during their peak water-use period. Some crops, like grain, may have their peak water-use period earlier than other crops. It is important to consider the cropping pattern on a farm because some conditions will require more water than others. For example, a small farm with permanent pasture would require a lower diversion rate than the same farm with a crop rotation consisting of beans and grain grown in alternate years, all other things

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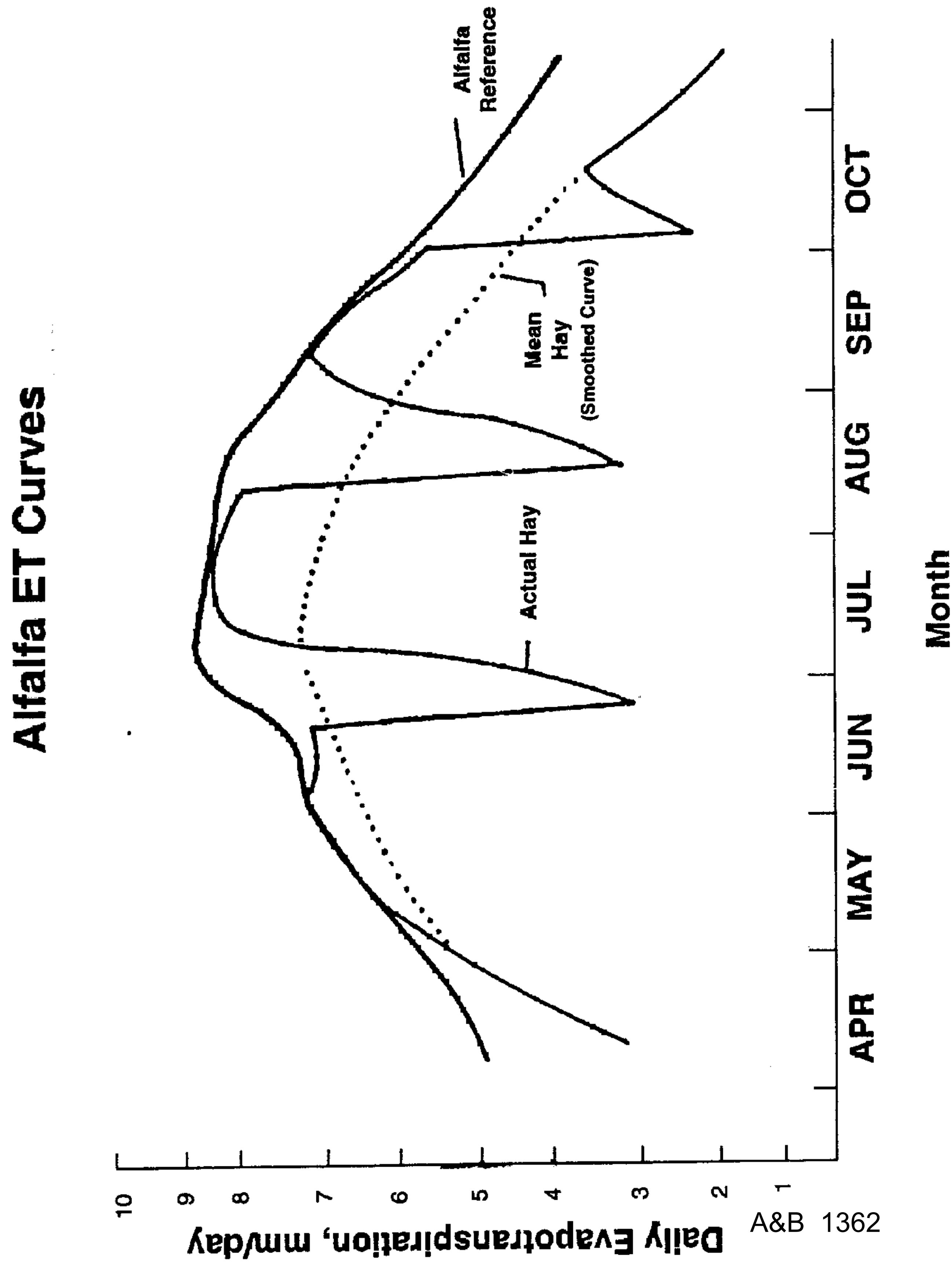
[7]The Allen and Brockway reference ET is based on alfalfa grown continuously without the effects of cuttings. The reference ET is a standard which other crops can be compared against to determine ET estimates for those crops.

[8]Based on communication with James L. Wright of the U.S.D.A. Agricultural Research Service, June 4, 1996.

Figure 3



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being equal.[9] This is because in the years when beans are grown, the ET is much higher than the ET for pasture (or grain) during the peak water-use period. On farms growing multiple crops, the historical cropping pattern with the highest diversion requirements should be selected. This will establish the historical extent of water use for irrigation.

Probability Distribution

Crop ET requirements will vary from year to year for the same crop type in the same location. This is due to changes in the weather. "In selecting ET for project planning and design, knowledge should be obtained on [the] level and frequency at which high demands for water can be expected, particularly in the months of peak water use" (Doorenbos and Pruitt, 1977, p. 55). "Several recent studies have shown that the design ET rate should be based on a probability level of expected ET which changes throughout the growing season" (Jensen, 1983, p. 221). This is different than the procedure recommended in the Hubble report, which does not account for the variation in ET from year to year.

Historic climatic data is necessary to calculate a probability distribution of ET estimates. The Allen and Brockway monthly ET estimates include statistical outputs which can be used to calculate probability percentile values for the estimates.[10] An appropriate probability percentile value depends on many factors. Maximum crop production on the farm is one goal but sizing a system to maximize production in all years may not be cost-effective. Diversion requirements based on maximum probable ET rates would not result in the optimum utilization of the water resources of the state and are not justified for resource allocation purposes. Doorenbos and Pruitt recommend a probability percentile value of 75 or 80 percent (Doorenbos and Pruitt, 1977, p. 56) and Hoffman et al. implied that irrigation systems in the western U.S. are commonly designed to fully utilize water supplies two years out of ten (Hoffman, Howell, and Solomon, 1990, pp. 636-637). This suggests that water is not fully utilized eight years out of ten which is equivalent to design based on an 80th percentile value. IDWR applies this criteria to determine ET requirements.

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[9]In all likelihood, all other things would not be equal. For example, the irrigation application efficiency may be different for each crop due to differences in crop root depth and other factors. Application efficiency must be considered along with ET rate to determine which crop has a higher diversion requirement.

[10]Assumption of normal distributions should give satisfactory results based on communication with C.E. Brockway of the University of Idaho Kimberly Research and Extension Center on April 17, 1996. Also see footnote 4.

IDWR has developed a computer spreadsheet to simplify the calculations required to determine the 80th percentile value of monthly ET. Figure 4 shows a sample output of the spreadsheet.

ET Estimates for Non-Reported Areas

Allen and Brockway's ET estimates at the 98 NOAA sites provide reasonable representation of the irrigated areas in the state. Some areas, such as the Hagerman Valley, have a unique local climate and are not well represented by any of the existing estimate sites. IDWR has considered other ET estimation methods for the Hagerman Valley, but the results of those methods are questionable due to the lack of appropriate climatic data.

In the University of Idaho's report to HWRO, the modified Penman method was used to estimate ET for the Hagerman Valley for the years 1991 and 1992 (Hazen, Gibson, and Neibling, 1994, p. 3). Temperature data were taken from a weather station near Hagerman and other climatic data were taken from a station near Kimberly. IDWR contacted the U.S. Bureau of Reclamation (BOR) for assistance to estimate ET for the Hagerman Valley using temperature data from Hagerman and other climatic data from an AgriMet station near Grandview (IDWR, 1996). BOR uses the 1982 Kimberly-Penman equation to estimate ET (USDI, BOR, 1995, p. 1). The Penman equation used in these estimates is very sensitive to changes in the climatic data used. The combination of temperature data from Hagerman and other climatic data from dissimilar stations resulted in questionable estimates due to that sensitivity.[11] Also, due to the lack of long-term temperature data for the Hagerman Valley, probability distributions could not be calculated.

In a method described by Brockway and Robison, the Allen and Brockway ET estimates from nearby stations can be adjusted for temperature and altitude to estimate ET for the Hagerman Valley or other locations.[12] Temperature adjustments are based on published sensitivity analysis of ET estimation methods (Brockway, et al., 1985). The Allen and Brockway ET estimates were based on actual monthly mean air temperature data from each location and secondary weather parameters from regional data. Regional secondary weather parameters were used because the data are only available at limited sites in Idaho. Since the estimates are primarily temperature dependent within a climatic region, adjustments for nearby stations based

[11]Based on communication with C.E. Brockway and Clarence Robison of the University of Idaho Kimberly Research and Extension Center on April 17, 1996.

[12]Based on communication with C.E. Brockway and Clarence Robison of the University of Idaho Kimberly Research and Extension Center, April 17, 1996.

FIGURE 4

80th Percentile Values of Monthly ET (mm/day)

Station: Emmett 2 E

		ETR	ALFH	ALFS	BEANS	F CRN	SILGE	S CRN	PEAS	POTAT	SBEET	SGRAN	WGRAN	PAST	ORCHD	VEGES	ONION	HOPS
April	AVE ET	4.78		3.74	0.00	0.00	0.00	0.00	1.52	1.43	1.43	1.54	4.53	3.44	2.03	0.00	1.54	1.49
April	STDD ET	0.41		0.32	0.00	0.00	0.00	0.00	0.13	0.12	0.12	0.13	0.39	0.30	0.17	0.00	0.13	0.13
April	80PCT ET	5.13	U	4.01	0.00	0.00	0.00	0.00	1.63	1.53	1.53	1.65	4.86	3.69	2.17	0.00	1.65	1.60
			S															
May	AVE ET	6.32	E	5.68	1.90	1.90	1.90	1.90	4.24	2.62	1.91	4.98	6.32	4.87	4.00	2.08	3.11	4.43
May	STDD ET	0.47		0.42	0.14	0.14	0.14	0.14	0.32	0.19	0.14	0.37	0.47	0.36	0.30	0.15	0.23	0.33
May	80PCT ET	6.72	E	6.03	2.02	2.02	2.02	2.02	4.51	2.78	2.03	5.29	6.72	5.17	4.25	2.21	3.30	4.71
			T															
June	AVE ET	7.92	R	6.75	4.01	3.67	3.67	3.75	5.85	6.27	4.18	7.90	7.92	6.10	6.48	4.80	5.19	7.51
June	STDD ET	0.46		0.39	0.23	0.21	0.21	0.22	0.34	0.36	0.24	0.46	0.46	0.35	0.38	0.28	0.30	0.44
June	80PCT ET	8.31	F	7.08	4.20	3.85	3.85	3.94	6.14	6.57	4.38	8.29	8.31	6.39	6.80	5.04	5.44	7.88
			O															
July	AVE ET	8.59	R	5.19	7.91	7.85	7.85	7.80	2.35	7.09	8.42	7.09	6.06	6.61	7.30	6.82	6.73	8.16
July	STDD ET	0.32		0.19	0.29	0.29	0.29	0.29	0.09	0.26	0.31	0.26	0.23	0.25	0.27	0.25	0.25	0.30
July	80PCT ET	8.86	A	5.35	8.15	8.09	8.09	8.04	2.43	7.31	8.68	7.31	6.25	6.82	7.53	7.03	6.94	8.41
			L															
August	AVE ET	7.11	F	2.88	3.44	6.51	6.51	6.13	0.00	5.21	6.92	1.45	1.17	5.47	6.04	5.55	5.69	6.74
August	STDD ET	0.34	A	0.14	0.17	0.31	0.31	0.29	0.00	0.25	0.33	0.07	0.06	0.26	0.29	0.27	0.27	0.32
August	80PCT ET	7.40	L	3.00	3.58	6.77	6.77	6.37	0.00	5.42	7.20	1.51	1.22	5.69	6.28	5.78	5.92	7.01
			F															
September	AVE ET	5.51	A	1.40	0.58	3.96	3.96	0.00	0.00	2.50	4.67	0.00	0.00	4.24	4.58	3.46	4.27	4.96
September	STDD ET	0.37		0.09	0.04	0.26	0.26	0.00	0.00	0.17	0.31	0.00	0.00	0.28	0.30	0.23	0.28	0.33
September	80PCT ET	5.82	H	1.48	0.61	4.18	4.18	0.00	0.00	2.64	4.93	0.00	0.00	4.48	4.83	3.65	4.51	5.24
			A															
October	AVE ET	3.34	Y	0.34	0.00	0.89	0.00	0.00	0.00	0.00	2.08	0.00	0.00	2.57	2.12	0.00	0.00	0.00
October	STDD ET	0.27		0.03	0.00	0.07	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.21	0.17	0.00	0.00	0.00
October	80PCT ET	3.57		0.37	0.00	0.95	0.00	0.00	0.00	0.00	2.22	0.00	0.00	2.75	2.26	0.00	0.00	0.00

ET and standard deviation data (AVE ET and STDD ET) taken from Appendix E (unpublished) of Brockway, C.E., and R.G. Allen, 1983, Estimating Consumptive Irrigation Requirements for Crops in Idaho, Idaho Water and Energy Resources Research Institute.

80th Percentile ET values (80PCT ET) calculated based on Walpole, R.E., and R.H. Meyers, 1985, third edition, PROBABILITY AND STATISTICS FOR ENGINEERS AND SCIENTISTS, New York: Macmillan Publishing Company, pp. 132-144 and 574.

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on temperature differences should give reasonable results. Temperature differences are based on springtime average temperature differences to avoid the effects of station aridity.[13]

The altitude adjustment used in the Allen and Brockway report is suggested by Doorenbos and Pruitt (Doorenbos and Pruitt, 1977, p. 4). The altitude adjustment is a ten percent decrease in ET for each 1000 meter increase in elevation.

The results of the method described are monthly ET estimates. Probability percentile values for the monthly estimates can be calculated as noted earlier. Monthly ET estimates (including 80th percentile values) for the Hagerman Valley adjusted from the Bliss station are presented in Appendix D. The values in Appendix D can be used to estimate peak period ET as described earlier in this report.

NET IRRIGATION APPLICATION

The net irrigation application represents the portion of the total amount of water applied during an irrigation that is available to satisfy the ET requirements of a crop.[14] It is also referred to as the application depth. The net irrigation application is one factor necessary to estimate the field application efficiency.

The design value used for the net irrigation application (also referred to as the design application depth) is the optimum or desired amount of water to be applied during an irrigation. Generally, larger design application depths will result in more efficient use of water for irrigation. This is because larger application depths reduce the frequency of irrigations required and therefore minimize the losses associated with the application of water. Several factors affect the determination of the design application depth. The primary factors are the crop root zone depth, available water capacity of the soil, and the crop stress level.

The crop root zone depth is the depth that a crop's roots penetrate the soil. Impervious hardpan or bedrock can limit the extent of root development in the soil profile. The root depth is also dependent on the crop type. Normal crop root depths for mature crops are shown in Appendix A-6 of the Hubble report guidelines. Knowledge of the crop root zone depth is necessary because irrigation water applied

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[13]Station aridity can affect ET estimates due to increased air temperature measurements at arid sites versus measurements over irrigated lands. The effects are least significant in the spring.

[14]The net irrigation application is not the total amount of water applied during an irrigation. When water is applied to a field, only a portion of that water is available for use by the crop. The remainder is called the application loss. Application losses will be discussed later in this report.

beyond the storage capacity of the soil within the root zone will percolate below the root zone and will not be available for use by the crop. This is an application loss called deep percolation.

The available water capacity (AWC) of the soil is the amount of water that can be stored in the soil and used by crops. AWC is dependent on the soil characteristics. Field capacity is the condition where soil moisture storage is at a maximum. Further irrigation beyond this point will result in deep percolation losses and, in some cases, additional surface runoff. When the available water in the soil is depleted to a point where plants can no longer remove water from the soil, the permanent wilting point is reached. Plants will wilt and die at this point.

Crops are subjected to stress at some point before reaching the permanent wilting point. This is due to the increased difficulty of water removal by the plants as the available water decreases in the root zone. At some point, full crop ET requirements will not be met and stress will result. This depends on the stress level (or stress point) of a particular crop. Many crops reach their stress level when about 50 percent of the total available water has been depleted. This means that when half of the field capacity amount has been used by the crop, the crop will begin to show signs of stress and a reduction of yields or crop quality may result. Maintaining the soil moisture in the crop root zone above the crop stress level will provide adequate moisture for full crop production.

It is desirable to allow crops to use the maximum amount of soil moisture in the crop root zone as long as the crop stress level is not exceeded. Management allowed deficit (MAD) is defined on page 60 of the Hubble report guidelines as "the amount of available water a crop can remove from the soil before the crop's growth or quality is affected." It is normally expressed as a depth of water removed from the root zone. MAD can also be viewed as the depth of water normally applied or replaced during an irrigation.

The normal irrigation application represents the amount of water (expressed as a percentage of the AWC) normally applied or replaced during an irrigation that will achieve the most efficient application of water. The normal irrigation application amount (based on crop stress level) for common crops is shown in Appendix A-6 of the Hubble report guidelines.

The design application depth can be quantified for specific conditions by determining the available water capacity (expressed as a depth of water) of the soil within the crop root zone and multiplying by the normal irrigation application amount for the crop (expressed in decimal form). This will be equivalent to the MAD (expressed as a depth of water).

Available Water Capacity

The available water capacity of a soil is dependent on many factors. Soil texture is a primary factor. The soil texture is determined by the proportion of the different sizes of particles that make up the soil. There are three general size categories to be considered: sand (largest), silt, and clay (smallest). Sandy soils are classified as coarse-textured soils. Loamy soils, which have proportionately similar amounts of sand, silt, and clay, are classified as medium-textured soils. Soils high in clay content are classified as fine-textured soils.

"Water is retained in the soil by a combination of the attraction of particle surfaces for water and the capillary action of water in the soil pores" (Jensen, 1983, p. 80). Coarse soils have the least amount of total particle surface area to attract water. They also have the least amount of capillary attraction due to the larger pore sizes. Therefore, water infiltrates coarse soils rapidly and drains easily, resulting in a relatively low AWC. Coarse or sandy soils require frequent irrigations because of their low AWC.

Fine soils have the greatest amount of total particle surface area and very small pore sizes. Since water is held very tightly in these soils the water infiltrates and drains very slowly. The water-retention capability is high but due to the properties of clay, the availability of that water to plants is reduced. Water must be applied slowly to fine soils or it may run off the surface before it infiltrates and occupies the pores within the soil.

Loamy or medium-textured soils are ideal for irrigation and plant growth. The infiltration rate is manageable and the AWC is still high.

Other factors that have an effect on AWC are the existence of gravel or other coarse fragments, organic matter content, and soil salinity. Also, the soil profile may be made up of several distinct layers of soil with different characteristics. These factors must be considered when determining AWC.

AWC of soils has already been determined for crop land in Idaho by NRCS. This information is available as published soil survey data or computer-generated tables from local NRCS offices. The Hubble report cautions that AWC values given in NRCS soil surveys published before 1981 need to be adjusted for texture, coarse fragments, organic matter and salinity. NRCS soil surveys published in 1981 or later and all computer-generated tables currently available include adjusted AWC values. Soil maps which show boundaries for different soil types are also available in the published soil surveys or from local NRCS offices. Appendix E shows a sample soil map and computer-generated tables with AWC and textural classifications for the soils.

The procedure for using AWC from NRCS data is given on pages 7 and 8 of the Hubble report workbook. The first step is to locate the field on the appropriate soil map and note the map unit symbol(s) which cover the field. If a field is covered by more than one soil map unit, only those that cover a significant portion of the field (ten percent or more of the total field area is considered significant) should be used. The NRCS AWC data is specified in units of inches of water per inch of soil for each soil layer in the profile. A range of AWC values is given for each soil layer. The ranges reflect the natural variability of the soil that can be expected on the land. The Hubble report recommends using the average values for each range. The table following page 7 of the Hubble report workbook can be used to tabulate the calculations. The AWC of each soil layer is found by multiplying the averaged AWC for that layer by the depth (in inches) of the soil layer. The total AWC for a specific depth (e.g. crop root zone depth) is found by accumulating the AWC for each layer or the proportional amount for any partial layer down to the desired depth. Figure 5 is an example using a soil type from Appendix E. The example gives the accumulated AWC at each soil layer and at even foot depths (crop root depths are specified in even foot depths).

Calculation of Net Irrigation Application

When the appropriate values of crop root zone depth, normal irrigation application amount (based on crop stress level), and AWC are determined the design value of net irrigation application can be calculated. It should be calculated for all crops considered, for each significant soil within each field. Page 8 of the Hubble report workbook describes the procedure to calculate the net irrigation application. The AWC at the appropriate crop root zone depth is multiplied by the decimal value of the normal irrigation application amount. The result is the MAD which is also the design value used for the net irrigation application.

The table following page 8 of the Hubble report workbook can be used to tabulate the calculations. This table already has appropriate values for crop rooting depth and stress point (normal irrigation application) from Appendix A-6 of the Hubble report guidelines. When using this table it should be remembered that the crop root zone depth may be limited by the existence of a hardpan or bedrock layer. Figure 6 gives an example using AWC values from the example in Figure 5.

IDWR has developed a computer spreadsheet to simplify the calculations required to determine AWC and MAD. The spreadsheet also includes soil data and calculations necessary to estimate the soil intake family which will be discussed later in this report. Figure 7 shows the spreadsheet with the same data and calculations used in Figures 5 and 6.

SNAKE RIVER ADJUDICATION
SOIL PROFILES

Figure 5

TECH: ______ DATE: ______

SOIL: SAMPLE		
DEPTH	AVAILABLE WATER	
0	0.12	0
12		1.44
14	0.04	1.68
24		2.08
36		2.56
48		3.04
60		3.52

SOIL:		
DEPTH	AVAILABLE WATER	
INCHES	IN/IN	INCHES

TECH: ______ DATE: ______

SOIL: HaB			
DEPTH	AVAILABLE WATER		
INCHES	IN/IN	INCHES	
0	0.12	—	
10	0.185	1.20	.12 × 10 = 1.20
12		1.57	(.185×2) + 1.20
24		3.79	(.185×12) + 1.57
36		6.01	(.185×12) + 3.79
46	0.155	7.86	(.185×10) + 6.01
48		8.17	(.155×2) + 7.86
60		10.03	(.155×12) + 8.17

SOIL:		
DEPTH	AVAILABLE WATER	
INCHES	IN/IN	INCHES

TECH: ______ DATE: ______

SOIL:		
DEPTH	AVAILABLE WATER	
INCHES	IN/IN	INCHES

SOIL:		
DEPTH	AVAILABLE WATER	
INCHES	IN/IN	INCHES

SNAKE RIVER ADJUDICATION
MANAGEMENT ALLOWED DEFICIT

DATE: ____________

TECH: ____________ NAME: ____________________ ID. NO. ____________

CROP			MANAGEMENT ALLOWED DEFICIT IN INCHES BY SOILS									
			WEATHER STATION									
NAME	ROOTING DEPTH FT.	STRESS POINT \4	NOTUS NO				HaB					
ALFH.	5	0.50	1.76		10.03	x .5	=5.01					
ALFS.	5	0.50										
BEANS	2	0.40			3.79	x .4	=1.51					
F.CRN	4	0.50	1.52		8.17	x .5	=4.08					
SILGE	4	0.50										
S.CRN	3	0.40	1.02									
PEAS	3	0.5										
POTAT	3	0.35	.90									
SBEET	5	0.50	1.76									
SGRAN	4	0.50	1.52		8.17	x .5	=4.08					
WGRAN	4	0.50										
PAST.	3	0.50	1.28		6.01	x .5	=3.00					
ORCHD	5	0.5										
HOPS	5	0.5										
LENTILS	3	0.5										
VEGES USE BELOW												
TOMAT	5	0.5										
TRCKA\1	1	0.35	.50									
TRCKA\2	2	0.35										
TRCKA\3	3	0.5										
MELON	5	0.5										

\1 LETTUCE, RADISHES, ONIONS

\2 CABBAGE, BROCCOLI, CAULIFLOWER, SPINACH

\3 TURNIPS, PARSNIPS, CARROTS

\4 FRACTION OF AWC AVAILABLE TO CROP

Figure 7

SOIL CHARACTERISTICS initials: date:

Soil Type = Harpt coarse sandy loam (HaB)
Source of Soils Data = SCS computer-generated tables for Gem County Area

soil depth (inches)		AWC (in/in)		PH		organic (%)		soil depth (ft)	AWC (inches)	intake family	
lower	upper	lower	upper	lower	upper	lower	upper			flood	furrow
0	10	0.11	0.13	6.1	7.3	1	2	1	1.57	2	0.55
10	46	0.16	0.21					2	3.79		
46	60	0.13	0.18					3	6.01		
								4	8.17	alternate method	
								5	10.03		
										3	0.7

Management Allowed Deficit (MAD)

crop	root depth (ft)	stress point	MAD (inches)
alfalfa (hay or seed)	5	0.5	5.01
corn (field or silage)	4	0.5	4.08
grain (winter or spring)	4	0.5	4.08
pasture (or grass hay)	3	0.5	3.00
other (enter below)			

IRRIGATION APPLICATION SYSTEMS

The most common water application methods can be classified generally as surface systems or sprinkler systems. Surface systems distribute water over the soil surface by gravity flow. Sprinkler systems apply water by spraying or sprinkling water through the air to the soil surface. The diversion rate necessary for any irrigation application system is dependent on the ET requirements of the crops grown and the losses associated with the application of water by the system.

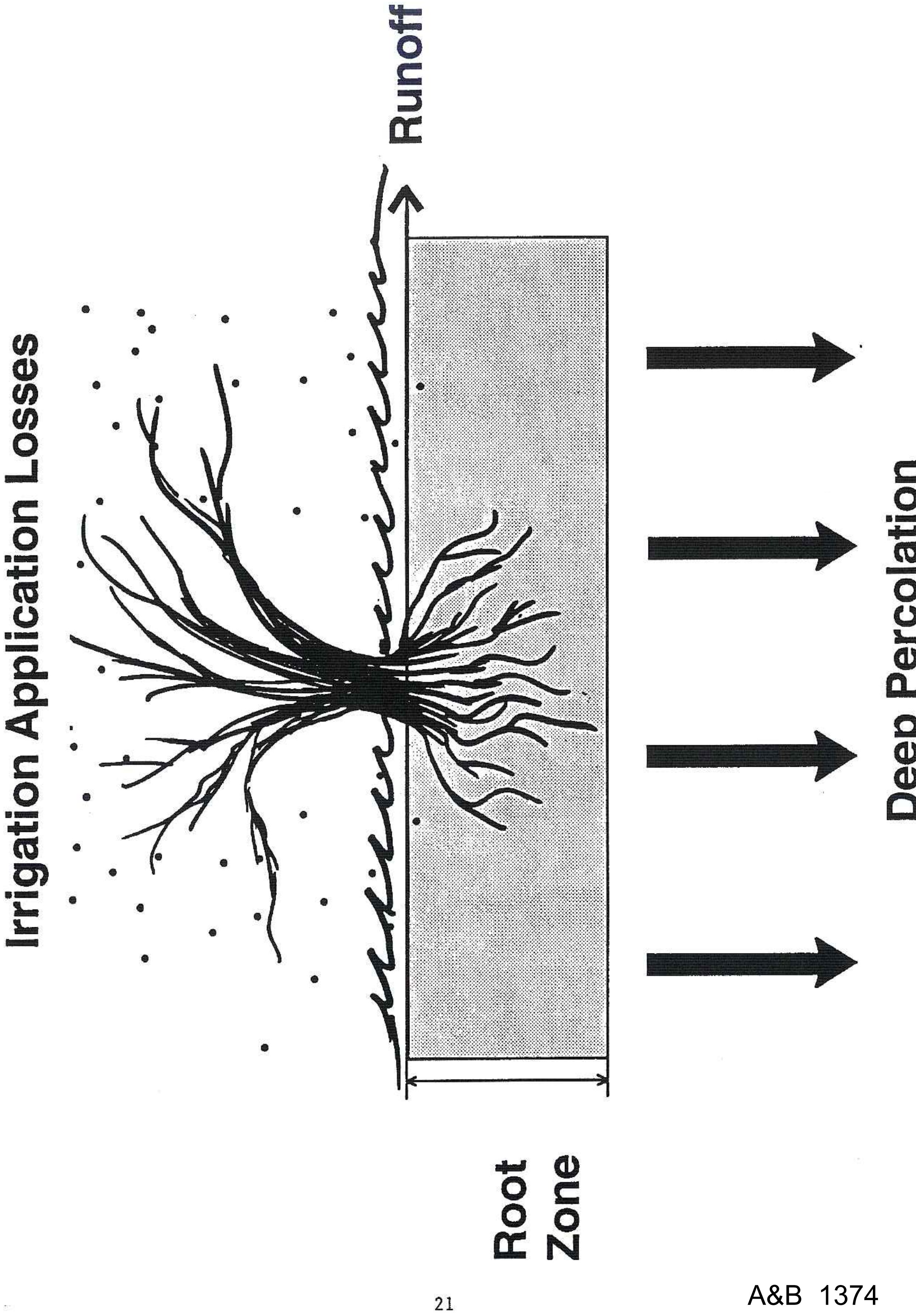
No irrigation system can apply water without some losses. The two primary application losses are runoff and deep percolation. Runoff occurs when water is applied to the soil surface at a faster rate than the water can infiltrate the soil. The water will run off to other parts of the field or off the field entirely. Deep percolation occurs when water is applied beyond the storage capacity of the soil within the crop root zone. The water moves downward below the crop root zone and is not available for use by the crop. Figure 8 is a simple drawing illustrating these losses. To account for the unavoidable losses, an amount greater than the net irrigation application must be applied to the fields. This amount is called the gross irrigation application. The gross irrigation application is expressed as a depth of water in inches.

Most irrigation systems apply water to manageable portions of a field, called sets, which are irrigated one at a time in succession until the field is completed. For each set, the gross irrigation application is applied over a period of time called the inflow time or the set time (expressed in hours). After the field is completed, it is not irrigated again until the amount of water available to the crop in the root zone is depleted to a point not exceeding the stress level of the crop. The time period between the start of successive irrigations of a field is called the irrigation interval or the irrigation frequency (expressed in number of days). The required irrigation interval during the peak water-use period can be calculated for a crop by dividing the crop's MAD by the peak period ET. This irrigation interval requires continuous use of the water during the peak water-use period to prevent crop stress.

Surface Irrigation Systems

Surface irrigation systems rely on gravity to distribute the water over the soil surface. Water is applied to a set from a ditch or a pipeline at the upper end of the field and progressively covers the set to the lower end. As the water moves across the soil surface it infiltrates the soil and is stored in the root zone where it becomes available for use by the crop. Some of the factors used to characterize a surface irrigation system are the infiltration rate of the soil, the gradient or slope of the field in the direction of flow, the length of the field in the direction of flow, and the method used to physically guide the water down the field. The inflow rate, set time and design

Figure 8


Irrigation Application Losses
Runoff
Deep Percolation
Root
Zone

application are management factors that the irrigator uses to apply the water to obtain a full irrigation with minimal losses.

There are many good references that describe, in detail, various kinds of surface irrigation systems.[15] The more common surface systems found in Idaho are briefly described below. These are furrow and corrugation systems, border systems, and wild flooding systems.

Furrow irrigation is the application of water through small, closely spaced channels used to guide the water down the field. The water does not flood the entire surface; instead, it is conveyed through the channels and infiltrates the soil both downward and laterally between the furrows. Water can be applied to the furrows through siphon tubes, from open ditches or from gated pipes.[16] An irrigation set consists of numerous furrows depending on the available supply of water. Corrugation irrigation is a type of furrow irrigation used on close-growing crops such as pasture, hay or grain. The channels are smaller and convey less water than other types of furrow systems.

Border irrigation is the application of water by flooding wide strips of land over the entire soil surface. The strips are bounded by ridges or dikes which are used to guide the water down the field. Water is applied at a rate sufficient for it to advance as a uniform sheet to the end of the field. An irrigation set consists of one or more border strips. Border irrigation is used on close-growing crops such as pasture, hay or grain.

Wild flooding is a surface flooding method where water is released from an open ditch and allowed to flow uncontrolled down to the end of the field. Typically, there is little or no land preparation attempted for these systems. In some cases, shallow soils or large rocks make land preparation impossible. Land irregularities result in uneven distribution of water and high application losses. Wild flooding systems are often used on marginal farm land to improve growth of native grasses or meadow hay.

<u>Soil Intake Family</u>

The rate at which water can move into the soil is called the soil infiltration rate (usually expressed as a depth of water infiltrated per hour). This is an important factor in surface irrigation system design or evaluation. In order to minimize application losses there must be a balance between the amount of water infiltrating

[15] See (Jensen, 1983).

[16] Gated pipe is portable pipe with small gates (used for flow control) used to distribute water into furrows.

the soil and the amount required to evenly distribute the water as it moves to the end of the field. A high infiltration rate can result in excessive deep percolation losses at the upper end of a field before the crop root zone is filled at the lower end. This is because water is in contact with the soil surface at the upper end for a longer period of time and at a higher rate than it is at the lower end. A low infiltration rate can result in excessive runoff at the lower end of the field because the time it takes for water to fill the crop root zone is much greater than the time it takes for the water to advance to the end of the field. Appropriate selection of field length, set time, inflow rate and other factors with regard to the soil infiltration rate can help to minimize these losses.

The infiltration rate or intake rate of a soil is dependent on the characteristics of the soil. Soil texture is a primary factor but other factors can influence the soil intake rate. In general, soil intake rate is highest for coarse-textured or sandy soils. This is due to their low soil particle surface area and large pore sizes which allow quick drainage of water.

Soil intake rate also varies with the soil moisture level. As water is added to the soil through irrigation the intake rate will initially decline and then stabilize. NRCS developed a series of general groups called intake families that relate the cumulative depth of infiltration to the time water is in contact with the soil surface. Soils with similar intake characteristics can be grouped into one of these intake families.

Soil intake family is dependent on the type of irrigation application system used. Water infiltrates surface flooding systems (e.g. border systems) by moving downward from the soil surface. Furrow systems rely on vertical and horizontal infiltration from the furrows. The cumulative depth of water infiltrated for each system type is different over the same time period for the same soil, so the intake family assigned to that soil would be different for each system type.

Ideally, soil intake family for an irrigation application system would be determined by on-site measurements to obtain the most accurate results. Due to resource constraints, it is impractical for IDWR to determine soil intake family by on-site measurements for every system being evaluated. The Hubble report guidelines provide a procedure to estimate soil intake families for surface irrigation systems beginning on page 47.

Soil intake families for flood type systems are based on soil texture and are adjusted for the organic matter and sodium content (indicated by pH level) of the soils. NRCS soil maps are used to identify the significant soil types in a field (soil types covering ten percent or more of the total field area is considered significant). The soil texture of the surface soil layer is identified using NRCS data from published soil surveys or computer-generated tables. NRCS data are also used to identify the organic matter content and the soil reaction (pH) for the surface soil layer (see Appendix E).

The flood intake family is initially identified based on the soil texture using the table from Appendix A-2 of the Hubble report guidelines. The flood intake family is modified for organic content by increasing one intake family for soils with two to five percent organic matter and increasing two intake families for soils with more than five percent organic matter. This organic matter adjustment is not necessary for soils with surface layer textures of sand, very fine sand, or loamy sand. The flood intake family is modified for soil reaction (pH) by decreasing one intake family for soils with pH of 8.5 to 9.0 and decreasing two intake families for soils with pH of 9.0 to 9.5.

Flood intake family can also be determined for many soils in Idaho by using Appendix A-3 of the Hubble report guidelines. This is a further refinement of the adjustment procedure presented above and it should be used where possible.

Furrow intake family can be determined for a soil by first determining the flood intake family for that soil and then using the table from Appendix A-2 of the Hubble report guidelines to convert to a furrow intake family. The conversion is based on a relationship between flood intake values and furrow intake trials run on soils in Idaho and southeastern Oregon (Hubble Engineering and Associated Earth Sciences, 1991b, p. 49 and Appendix A-2). Figure 9 gives an example of flood and furrow intake family determination for a soil type from Appendix E.

The spreadsheet developed by IDWR to determine AWC and MAD from NRCS soil data (see Figure 7) also simplifies the procedure to determine flood and furrow intake families. The alternate method shown in Figure 7 is based on Appendix A-3 of the Hubble report guidelines or actual measured values if available. The alternate or measured values should be used when available.

<u>Sprinkler Irrigation Systems</u>

Sprinkler irrigation systems apply water under pressure through nozzles which spray or sprinkle water through the air and onto the soil surface. When the water reaches the soil surface it infiltrates the soil[17] and is stored in the root zone where it becomes available for use by the crop. Some of the factors that characterize a sprinkler system are the water application rate, the size and spacings of nozzles, and the configuration of the pipe distribution system used to convey the water to the nozzles. Sprinkler systems are adaptable to many crops, soils, and topographic conditions.

[17]If the water application rate exceeds the intake rate of the soil, some of the water applied may be lost to surface runoff.

SOIL INTAKE FAMILY - EXAMPLE

SEE APPENDIX E

SOIL TYPE - Harpt coarse sandy loam (HaB)

ORGANIC MATTER - 1-2%

pH - 6.1 - 7.3

INITIAL FLOOD INTAKE FAMILY BASED ON SOIL TEXTURE = 2.0 (APPENDIX A-2 OF HUBBLE REPORT GUIDELINES)

NO ORGANIC MATTER ADJUSTMENT

NO SODIUM CONTENT (pH) ADJUSTMENT

FLOOD INTAKE FAMILY = 2.0

FURROW INTAKE FAMILY = 0.55

ALTERNATIVE DETERMINATION USING APPENDIX A-3-1 OF HUBBLE REPORT GUIDELINES

FLOOD INTAKE FAMILY = 3.0

FURROW INTAKE FAMILY = 0.7

ALTERNATIVE VALUES ARE CONSIDERED REFINEMENTS OF PROCEDURE ABOVE AND ARE RECOMMENDED FOR USE WHEN AVAILABLE

Sprinkler systems utilize pressurized pipelines in various configurations to convey water to sprinkler nozzles of various sizes and spacings. Due to the variety of pipe configurations, nozzle sizes, and nozzle spacings available, the water can be uniformly distributed over the soil surface. This is a sharp contrast to surface irrigation systems which rely heavily on the soil characteristics to distribute water across the field. Runoff losses are minimal as long as water is applied at a rate which does not exceed the infiltration rate of the soil. Deep percolation losses are minimal as long as water is applied for an appropriate period of time so that the design application depth is not exceeded.

There are many types of sprinkler irrigation systems used today. They are usually classified based on the way that the pipe distribution systems are operated. Some of the more common systems are portable (hand-move), side-roll (wheel line), solid set, center pivot, and linear move. There are many good references that describe, in detail, the various kinds of sprinkler irrigation systems.[18]

System Description

An accurate description of the irrigation application systems on a farm is necessary for a proper evaluation. Information is required for each field because the combination of field dimensions, system configuration, and system management will have a large influence on the efficiency of water application for each field. It is especially important to include a good map or drawing identifying each field, field dimensions, location of ditches or pipelines, direction of flow, and information specific to the type of application system. The description should also include farm cropping patterns and crop rotations, set times, and irrigation frequencies (during the peak water-use period) for each field.

A questionnaire was developed to aid in data collection (see Appendix F). The irrigator is the best source for most of the information concerning the application system. The questionnaire can also be used as an inventory list by the evaluator during on-site visits. In some cases, information from the questionnaire will need to be supplemented with information from aerial photographs, topographic maps and on-site measurements.

[18]See (Jensen, 1983).

FIELD APPLICATION EFFICIENCY

The field application efficiency (FAE) is defined as an "expression in percent of the amount of water applied to a field that becomes available to the crop" (Hubble Engineering and Associated Earth Sciences, 1991b, p. 60). After an irrigation, the gross irrigation application is not entirely available to the crop. Some of the water is lost to deep percolation, runoff or other losses. These losses are not stored in the crop root zone and are not available to satisfy the ET requirements of the crop. The net irrigation application, as explained earlier in this report, is that portion of the total amount of water applied during an irrigation that is available to satisfy the ET requirements of the crop. FAE can be calculated by dividing the net irrigation application by the gross irrigation application and then multiplying by 100.

Typical or expected values of FAE can be found in existing literature. Some typical FAE values for various systems are as follows: 30 to 80 percent for furrow irrigation systems, 35 to 75 percent for graded border systems, and 50 to 87 percent for sprinkler systems (Idaho Irrigation Water Conservation Task Force, 1994, p. 38). The higher values for each of the ranges given are typical for well designed and properly managed irrigation systems.

The FAE is used, along with the ET requirements of the crop, to determine the field irrigation requirements. The FAE depends on the irrigation system type, system design, and management. Many other factors can influence the FAE such as soil characteristics and field dimensions.

Reasonable Efficiency

The determination of the necessity of an irrigation diversion rate greater than 0.02 cfs per acre must include the determination of reasonable field application efficiencies based on acceptable irrigation practices. IDWR has strived to balance the needs of individual water users with the needs of all water users in order to provide for the greatest benefit from the resource while maintaining seniority protection. Designation of a minimum acceptable FAE was considered as one option to apply to all irrigation systems but that option does not consider the unique combination of conditions that may exist for each individual system on a farm or for various locations around the state.

Economic feasibility plays a large part in the selection of irrigation methods used by a farmer. Other factors include water availability, physical limitations of the land, crop types and water requirements, and local customs and practices, to name a few. These factors need to be considered when determining reasonable efficiencies. "The Department [IDWR] does not intend to place an insurmountable financial burden upon farmers by requiring huge capital expenditures to change and improve their systems in order to obtain higher efficiencies. Instead, the determination of a reasonable efficiency should focus on proper management and low-cost improvements that can be made within the confines of the existing system types and soil characteristics" (IDWR, 1992).

The Hubble report guidelines provide a variety of procedures to estimate FAE. Several alternatives for efficiency improvement are suggested as well. Reasonable efficiencies will be determined based on the optimum FAE estimated using acceptable alternative irrigation practices. The optimum FAE should be calculated for each field based on the historical cropping pattern of the farm with the highest diversion requirements. Procedures to determine the optimum FAE are provided below for the more common systems found in the state.

Furrow Irrigation Systems

The optimum FAE will be estimated for furrow irrigation systems by considering the individual factors that affect efficiency and by examining practical alternatives based on acceptable irrigation practices. A computer program, developed by NRCS, was provided with the Hubble report to estimate FAE for furrow and corrugation irrigation systems. The program inputs can be changed to see the effects of alternative irrigation practices. The Hubble report guidelines (beginning on page 57) provide several alternative irrigation practices for consideration. The optimum FAE will be estimated using some of these alternatives as described below.

Each field should be evaluated separately unless conditions are similar enough to justify simplification by combining fields. In some cases, fields may need to be split and evaluated in parts due to dissimilar conditions or extreme lengths.

The NRCS furrow program requires inputs of furrow intake family, design application (inches), furrow slope (ft/ft), furrow spacing (ft), furrow length (ft), inflow rate (gpm), and inflow time (hrs). Program outputs include advance time[19] (minutes), gross irrigation application (inches), net irrigation application[20] (inches), runoff (inches), deep percolation (inches), and irrigation efficiency (percent). A full irrigation is attained

[19]Advance time is the time required for the furrow stream to reach the lower end of the field.

[20]The net irrigation application used in the program is the total depth of water applied at the lower end of the field. This is used as a comparison to the design application to indicate when the design application has been met or exceeded throughout the entire field length. This is not the same as the net irrigation application defined elsewhere in this report.

when the net irrigation application equals or exceeds the design application. The irrigation efficiency is equal to the design application divided by the gross irrigation application. FAE estimates below 15 percent and above 70 percent are considered outside the practical limits of the program.[21] An FAE greater than 70 percent may also be an unrealistic expectation in actual practice without a higher level of design. If FAE estimates by the program are outside these limits, then values of 15 percent or 70 percent should be used instead. Figure 10 is a sample output from the furrow program.

The furrow intake family and design application are determined, based on soil and crop characteristics, as described earlier in this report. If two or more dissimilar soil types exist in a field, it may be necessary to split the field and evaluate each portion separately. The NRCS recommends that soil characteristics should be considered during layout of an irrigation system. "Where soils have appreciable differences in intake rate and water-holding capacity, the fields should be divided as nearly along soil boundaries as is practicable and provide uniform row lengths" (USDA, SCS, 1984, p. 5-13). For evaluation of existing fields the determination of an appropriate split will depend on the location and configuration of the soil boundaries.

If a soil boundary closely parallels the direction of flow in the field, then it may be appropriate to evaluate each section separately. Efficient use of water, in such cases, would require an irrigator to manage each section differently.

If a soil boundary runs perpendicular to the direction of flow in the field, the intake rate of the soil should be considered. "The outlet end of the rows can cross the boundary between a slow intake rate soil and a somewhat higher intake rate soil and still permit efficient application. Crossing the boundary between a high intake rate soil and a lower intake rate soil for any appreciable distance should be avoided" (USDA, SCS, 1984, p. 5-13). A field can be split across the direction of flow by using cross-ditches or gated pipe to supply water at the desired location. For evaluation of existing systems, splitting the field length should only be considered in extreme cases where a proper analysis would not be otherwise possible.

In some cases it may not be practical to split a field for better water management. This may be due to random occurrences of different soils or resultant field lengths which are impractical for other farm cultivation practices (lengths of 300 feet are considered a minimum practical length for evaluation purposes). In these cases the

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[21]Based on communication with C.E. Brockway and Clarence Robison of the University of Idaho Kimberly Research and Extension Center on April 17, 1996. The NRCS furrow program is considered reasonably accurate within these limits when appropriate inputs are used.

Figure 10
NRCS Furrow Program

INTAKE FAMILY	DESIGN APPLIC. Inches	FURROW SLOPE Ft/Ft	FURROW SPACING Feet	FURROW LENGTH Feet	INFLOW RATE Gpm	APPROXIMATE INFLOW TIME Hours	ADVANCE TIME Minutes	GROSS IRRIGATION APPLICATION Inches	NET IRRIGATION APPLICATION Inches	RUNOFF Inches	DEEP PERC. In.	IRRIGATION EFFICIENCY %
0.70	1.50	.004	2.50	1200	12	12	509.7	4.62	2.04	0.32	2.80	32.47
0.70	1.50	.004	2.50	1200	15	8	312.2	3.85	1.82	0.53	1.82	38.96
0.70	1.50	.004	2.50	600	5	12	416.1	3.85	2.27	0.01	2.34	38.96
0.70	1.50	.004	2.50	600	6	8	254.9	3.08	1.89	0.15	1.43	48.70

evaluation of the field should be based on the soil with intake family and MAD values that result in the lowest attainable efficiencies. This will ensure that the crop will not be stressed in certain parts of the field.

The furrow slope is the ratio of the elevation difference between the upper and lower ends of the field to the horizontal distance between the ends of the field (in the direction of flow). Furrow slope information can be obtained from the irrigator (if known), from topographic maps of the area, or from on-site measurements. Graded furrow irrigation systems are best suited to land with slopes ranging from 0.1 to 3 percent (0.001 to 0.03 ft/ft) in arid areas and corrugation systems are best suited to land with slopes ranging from 1 to 4 percent (0.01 to 0.04 ft/ft) (USDA, SCS, 1984, pp. 5-6 and 5-11). On fields where the soil surface is uneven, land leveling will help provide more uniform water application. A major slope change may be cost-prohibitive and is not considered a practical alternative irrigation practice.

The furrow spacing is the distance measured between the furrows in a field. The furrow spacing can be obtained from the irrigator, or from on-site measurements. If alternate-row irrigation is practiced during the peak water-use period, the spacing to be used in the program is the distance between the furrows where water is actually applied during an irrigation. Although a change in furrow spacing can affect the FAE, the spacing must be compatible with the crops grown and with the farm machinery used so changes may not be practical.

The furrow length is the length of the furrows in the direction of flow. The furrow length can be obtained from the irrigator, from aerial photography, or from on-site measurements. The length representative of the majority of the furrows in the field should be used. The average length can be used if the furrow lengths are fairly uniform. If furrow lengths vary significantly, the field may need to be split with each portion evaluated separately.

The optimum furrow length for efficient water use is very dependent on the intake rate of the soil. "Other factors being equal, furrows must be much shorter on coarse-textured soils with high intake rates than on fine-textured soils with low intake rates" (USDA, SCS, 1984, p. 5-19). Long furrow lengths used on fields with high intake rate soils can result in excessive deep percolation losses at the upper end of the field and incomplete irrigation at the lower end of the field. This is because the water is in contact with the soil surface at the upper end of the field for a longer period of time and at a higher rate than it is at the lower end.

As explained earlier, the furrow length can be reduced by use of cross-ditches or gated pipe to divide the field in half or in thirds as long as lengths are not reduced below practical limits (300 foot minimum lengths). Soil boundaries must be considered along with optimum length before determining the placement of cross-ditches or gated pipe. For evaluation of existing systems, splitting the field length should only be considered where the analysis indicates an incomplete irrigation due to extreme furrow lengths.

The inflow rate is the rate of flow into an individual furrow. Changes in inflow rate will have a significant effect on the FAE. A high inflow rate can reduce deep percolation losses in fields with high intake rate soils. The high flow rate will allow the water to advance to the end of the field faster. This reduces the difference in infiltration time between the upper and lower ends of the field. The result is a more uniform application of water and less deep percolation. A low inflow rate can reduce runoff losses in fields with low intake rate soils. Since water infiltrates slowly, a low inflow rate will limit the amount of runoff at the end of the field.

Inflow rate is limited by the carrying capacity of the furrow. A practical upper limit of inflow rate for furrows is 50 gpm and for corrugations is 10 gpm (USDA, SCS, 1984, p. 5-23). Inflow rate is also limited by soil erosion. The maximum nonerosive inflow rate (in gpm) for erodible soils can be calculated as 10 divided by the furrow slope (in percent) for furrows and 40 divided by the slope for corrugations (USDA, SCS, 1984, p. 5-23). A practical lower limit of inflow rate for both furrows and corrugations is three gpm.[22]

The optimum inflow rate can be found for various conditions using the furrow program. Start with an inflow rate that does not exceed the capacity limit or the erosive flow limit and then decrease the inflow values to the lowest value (but not less than three gpm) which still allows the design application to be met (the program will indicate when the design application is no longer met). In some cases, an increase in the inflow time or set time is required to meet the design application value specified.

The inflow time is the amount of time water is applied to an irrigation set. The inflow time can have a significant effect on the FAE. Deep percolation and runoff losses will increase if the inflow time exceeds the amount of time necessary to fill the crop root zone. The inflow time is usually some multiple of 12 hours although 8 hours or less is not uncommon for many systems. A reasonable FAE may not be attainable on high intake rate soils unless the inflow time is relatively short. Inflow times shorter than 12 hours are not considered practical on a continuous basis.

The optimum inflow time can be found for various conditions using the computer program. Start with a 12-hour inflow time and find the optimum inflow rate as described above. If the design application cannot be met without exceeding inflow

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[22]Based on communication with Burke Scholer of IDWR on September 18, 1997.

rate limits, then change the inflow time to 24 hours or more in increments of 12 hours. Continue as above until the optimum inflow rate is found. In some cases, a longer set time may result in a higher FAE.

Several runs of the program using various lengths, inflow times, and inflow rates may be required to find the optimum FAE. The procedure can be summarized as follows. Using the NRCS furrow program (analysis option), input the appropriate values of furrow intake family, design application, furrow slope, and furrow spacing. Start with the existing furrow lengths and an inflow time of 12 hours. Input the maximum inflow rate (based on furrow capacity and maximum nonerosive flow). If the design application is not met, then increase the inflow time to 24 hours or more in increments of 12 hours. When the design application is met, decrease the inflow rate to the lowest value which still allows the design application to be met (but not less than three gpm). If it is apparent that the design application cannot be met with reasonable set times, then repeat this process using shorter furrow lengths. Next, compare the efficiencies resulting from each trial. The highest efficiency will be the optimum FAE. Figures 11 and 12 present optimum FAE estimates for various furrow lengths, slopes, and application depths for a loamy sand or similar type soil (0.7 intake family) using 2.5 foot furrow spacings and the procedure described above.

The procedure to determine the optimum FAE for furrow irrigation systems will serve as a standard for comparison to other surface irrigation systems. Furrow systems are adaptable to many types of crops, they are flexible regarding the available water supply, and they reflect the necessity of flow rates greater than 0.02 cfs per acre under various combinations of crops, soils, and field conditions.

Graded Border Irrigation Systems

Under the right conditions, border irrigation can be a highly efficient method of irrigation. "Border-strip irrigation is complicated and requires the highest level of management skill of any surface irrigation method to achieve high efficiencies" (Jensen, 1983, p. 733). The inflow rate must be high enough to spread evenly across the border strip and advance to the end of the field as a continuous "sheet" of water. Water flow into the border strip is generally shut off before the stream reaches the end of the field. This prevents excessive runoff because the water already in the field will continue to infiltrate the soil as it advances to the end of the field. Appropriate inflow rates and set times are required to ensure that the design application depth is not exceeded. These values are very dependent on the intake rate of the soil and the border length. A computer program, developed by NRCS, was provided with the Hubble report to estimate FAE for border irrigation systems. This program can be used to estimate the appropriate inflow rate for an existing system. Experience with the program has shown that border systems require high inflow rates and short inflow

Figure 11

Optimum Field Application Efficiencies (%) - Furrow[1]					
Length (feet)	Slope (ft/ft)	Design Application Depth (inches) 1	1.5	2	2.5
300	.001	16	24	32	36
300	.005	22	32	43	54
300	.01	22	32	43	54
300	.03	22	32	43	54
600	.001	14*	22	27	32
600	.005	24	35	47	59
600	.01	26	39	52	65
600	.03	12*	19	25	31
900	.001	13*	19	24	30
900	.005	24	37	49	61
900	.01	24	37	49	61
900	.03				
1200	.001	12*	17	23	28
1200	.005	24	35	47	54
1200	.01	14*	21	27	34
1200	.03				

[1] Based on NRCS Furrow program under conditions described below:
- loamy sand or similar type soils with furrow intake family of 0.7
- set times of 12, 24, or 36 hours
- furrow spacing of 2.5 feet
- maximum furrow inflow of 10/S up to 50 gpm capacity (S=slope in %)
- minimum furrow inflow of 3 gpm
- design application depths are typical for crops in sandy soils
- * indicates efficiencies greater than 70% or less than 15% which are outside recommended limits of program
- [blank] represents conditions not recommended due to erosive flow requirements

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Figure 12

Optimum Field Application Efficiencies (%) - Corrugation[1]				
Length (feet)	Slope (ft/ft)	Design Application Depth (inches) 1.5	2	2.5
300	.001	24	32	41
300	.005	32	43	54
300	.01	32	43	54
300	.02	32	43	54
300	.04	32	43	54
600	.001	22	29	34
600	.005	30	40	50
600	.01	32	43	54
600	.02	32	43	54
600	.04	35	47	59
900	.001			
900	.005	16	22	27
900	.01	29	39	49
900	.02	31	41	51
900	.04	34	46	57
1200	.001			
1200	.005			
1200	.01			
1200	.02	14*	18	23
1200	.04	19	26	32

[1] Based on NRCS Furrow program under conditions described below:

- loamy sand or similar type soils with furrow intake family of 0.7
- set times of 12, 24, or 36 hours
- corrugation spacing of 2.5 feet
- maximum corrugation inflow of 40/S up to 10 gpm capacity (S=slope in %)
- minimum corrugation inflow of 3 gpm
- design application depths are typical for crops in sandy soils
- * indicates efficiencies greater than 70% or less than 15% which are outside recommended limits of program
- [blank] represents conditions not recommended due to erosive flow requirements

times in order to obtain acceptable efficiencies. This is especially true for high intake rate soils. Appendix G shows several runs of the program for a typical border strip in a loamy sand or similar type soil (3.0 flood intake family). Acceptable application efficiencies are not achievable for these soils unless the set times are substantially less than 12 hours. However, set times less than 12 hours are not considered practical on a continuous basis.

Most fields using border irrigation systems require large flows on an intermittent basis. Water is not required continuously because the field or fields can be irrigated in a very short time. This period of time is usually much shorter than the required irrigation frequency during the peak water-use period. For water allocation purposes, the diversion rate required for irrigation must be based on the amount of water required on a continuous basis during the peak water-use period. This is to ensure a dependable supply of water for other water users.

Since border irrigation systems require high flows and short set times on an intermittent basis, use of the FAE estimated by the border program will not result in a determination of field irrigation requirements based on continuous use of the water. Because of this, the border program will not be used to estimate the optimum FAE for border systems. Instead, the procedure described above for corrugation systems using the furrow program will be used as a standard to determine the optimum FAE for border systems. Corrugation systems are adaptable to the same types of crops as border systems. They are flexible regarding the use of a continuous supply of water. And, they reflect the necessity of diversion rates greater than 0.02 cfs per acre under conditions very similar to those found on border irrigation systems. The procedure described above for corrugation systems should be followed using the appropriate furrow intake family and design application, the existing field slope, and a reasonable corrugation spacing. For consistency, use 2.5 feet for alfalfa and 2 feet for pasture and grain. The optimum lengths, inflow rates, and inflow times obtained from the furrow program will provide an optimum FAE to be used in the determination of the field irrigation requirements.

It should be noted that the use of the furrow irrigation procedure as a standard does not prohibit the use of border irrigation systems. The use of border irrigation systems is considered an acceptable irrigation practice. Water can be applied very efficiently where a flexible water supply exists. Flexible water supplies often exist on large farms with multiple crops and systems, farms with storage reservoirs, and canal companies or other situations where water rotation is practiced.

Wild Flooding Irrigation Systems

Wild flooding systems are common in many parts of the state. They are most commonly used on farmland with marginal value where other types of water application systems are not economical or practical. Land preparation and improvements are minimal or nonexistent and the water management level is very low.

Wild flooding irrigation systems are not like other surface irrigation systems which retain some control of the water as it flows down to the end of the field. The distribution of water is very dependent on the condition of the land surface. After leaving the supply ditch, the water spreads randomly to low spots and infiltrates the soil as it moves towards the end of the field. Long set times are normal to allow the water to spread laterally through the soil from the braided streams that form on the land surface. Due to the lack of control on the water, the distribution is often uneven and the FAE is usually very low. In general, this method of water application is not considered an acceptable irrigation practice.

The level of benefit gained to crops irrigated with wild flooding systems is variable and primarily dependent on the condition of the land where the systems are used. When comparing the amount of water applied and the benefit gained between wild flooding systems and conventional surface irrigation systems, the level of efficiencies cannot be justified for water allocation purposes.

Since there is some benefit gained from these systems, there is a need for a standard, based on acceptable irrigation practices, to determine an acceptable level of efficiencies for wild flooding systems. The procedure described above for corrugation systems using the furrow program will be used as a standard to determine the optimum FAE for wild flooding systems. The procedure for corrugation systems should be followed using the appropriate furrow intake family and design application, the existing field slope, and a reasonable corrugation spacing. For consistency, use 2.5 feet for alfalfa and 2 feet for pasture and grain. The optimum lengths, inflow rates, and inflow times obtained from the furrow program will provide an optimum FAE to be used in the determination of the field irrigation requirements.

In some cases, wild flooding systems are used in isolated areas, near the headwaters of small drainage basins or along intermittent streams. These systems rely heavily on spring runoff. Water is diverted early in the season when spring runoff occurs and allowed to flood lands adjacent to the source. Runoff from the fields flows back into the stream where it becomes available for other fields or other farms situated downstream. In these situations, the amount of water available is controlled by the amount of spring runoff; water application losses have no real effect on water users downstream because the losses end up back in the stream. Upstream water users, if they exist, generally share the same practices and operate under the same local customs or understandings. In these cases, where no impacts or potential injury to other water users can be identified, the diversion rates required under the existing systems and conditions are considered reasonable and necessary.

Sprinkler Irrigation Systems

Sprinkler irrigation systems are typically more efficient than surface irrigation systems. Historically, many surface systems have been replaced by sprinkler systems. The decision to use a particular irrigation system may depend on factors beyond the control of the farmer (e.g. crop prices, energy costs). To overcome the variability of those factors, farmers should be allowed some flexibility to return to a surface system as necessary. In cases where a water right was originally developed as a surface system, the optimum FAE will be based on the surface system using acceptable irrigation practices as described earlier in this report.

For those sprinkler systems which were originally developed as sprinkler systems, the optimum FAE will be estimated based on typical or expected values found in existing literature. Sprinkler systems are very flexible in their ability to apply water at the necessary rates and time periods for various crops and soil conditions. Properly designed and managed systems will achieve these expected efficiencies under normal conditions.

The Hubble report guidelines (page 25 and Appendix A-7) provide a range of efficiencies for various types of sprinkler systems. The University of Idaho questioned the reasonableness of these efficiency values in their report to HWRO (Hazen, Gibson, and Neibling, 1994, p. 9). The University of Idaho report provided an alternative range of efficiencies for various types of sprinkler systems. These values were originally presented in a 1994 report by the Idaho Irrigation Water Conservation Task Force and are reprinted below (Idaho Irrigation Water Conservation Task Force, 1994, p. 38).

sprinkler system	application efficiency
stationary lateral (wheel or hand move)	60 - 75%
solid set lateral	60 - 85%
traveling big gun	55 - 67%
stationary big gun	50 - 60%
center pivot lateral	75 - 85%
moving lateral (linear)	80 - 87%

The average values for each range can be used for normal conditions. In windy areas, use of the lower values may be warranted because wind can have a large impact on the FAE of sprinkler systems and it may be difficult to overcome for some system types.

A complete description of the sprinkler system used on a farm is helpful for evaluation purposes. The description should include a good drawing or map showing the layout for the type of sprinkler system(s) used. The description should also include the historical cropping pattern for the farm. Knowledge of the nozzle sizes, spacings, and operating pressures can be used to estimate the water application rate of a system based on sprinkler manufacturer's specifications or other sprinkler system design literature. Other useful information includes the irrigation frequency and the irrigation set time.

The soil type in each field is necessary to determine the appropriate design application value. The design application value is necessary to determine the ratio used to estimate the peak period crop ET (described earlier in this report). If two or more soil types exist in a field, the design application value (MAD) should be based on the lowest value because sprinkler systems are generally operated on that basis. This is to ensure that the crop will not be stressed in certain parts of the field.

Other Irrigation Systems

Trickle or drip irrigation systems apply water directly to the soil around the plant roots through emitters which are situated on or beneath the soil surface. Due to the high level of control on the amount of water applied, these systems are very efficient. Typical application efficiencies range from 85 to 95 percent (Idaho Irrigation Water Conservation Task Force, 1994, p. 39). The Hubble report guidelines (page 28) suggest that trickle or drip irrigation systems should operate on diversion rates well within 0.02 cfs per acre.

There may be other types of irrigation systems or special circumstances which are not covered in this report. These will need to be evaluated on a case-by-case basis.

ON-FARM IRRIGATION REQUIREMENT

The on-farm irrigation requirement is the sum of the diversion rates required for each field on the farm during the peak water-use period. It should be based on the historical cropping pattern with the highest diversion requirements. The diversion rate required for each field is based on a reasonable FAE and the peak period crop ET. The reasonable FAE is the optimum FAE estimated for the irrigation system using acceptable irrigation practices. The field irrigation requirements can be calculated based on the equation described earlier in this report:

$$FIR = 4.2 \times (CU/FAE)$$

This equation is simply a calculation of the daily gross irrigation application (in inches) required for a field on a continuous basis (during the peak water-use period) and converted to units of cfs per acre.

The table following page 2 of the Hubble report workbook was intended for use as a summary of the calculations for the field irrigation requirements in order to determine the on-farm irrigation requirement. This table should not be used as instructed in the workbook (pages 2-4) because of an error identified in the procedure. Use of the procedure in the workbook will result in an incorrect determination of the on-farm irrigation requirement because it does not provide a proper summation of the individual field irrigation requirements (see Appendix H).

As an alternative to the Hubble report workbook procedure, IDWR has developed a computer spreadsheet to perform the calculations required to determine the on-farm irrigation requirement (see Figure 13). The spreadsheet requires input of the crop type, irrigated acres, system type, application efficiency, crop ET, and net irrigation application for each field. The application efficiency is the optimum FAE which is estimated as described earlier in this report. The crop ET values are the 80th percentile monthly crop ET values which are calculated as described earlier in this report. The net irrigation application is determined as described earlier in this report.

The spreadsheet calculates the daily gross irrigation application required during the peak water-use period of each month based on the peak period crop ET and the optimum FAE. The peak period crop ET is calculated within the spreadsheet using the appropriate ratio of peak period ET to monthly ET as described earlier in this report. The gross irrigation application values are summarized for each month using weighted averages (based on crop acreage) in order to identify the month when the gross irrigation application is highest on the farm for all the fields combined. The highest summary value of gross irrigation application is converted to units of cfs per acre and is output as the on-farm irrigation diversion requirement. This value is equal to the sum of the field irrigation requirements during the peak water-use period.

Since the field irrigation requirement equation is based on continuous use, an adjustment is required for hand move sprinkler systems because the operation time for these sprinkler systems is less than 24 hours per day. This is due to the time required to move the sprinkler pipe between irrigation sets. The easiest way to make the

Figure 13

FIELD IRRIGATION REQUIREMENT

initials: Claimant =

date: Weather Station = Bliss/Hagerman

crop	acres	irrig. system	eff. (%)	mar	Monthly ET (mm/day) apr	may	jun	jul	aug	sep	oct	AVE IR season (mm/yr)	net irrig. app. (in)	ET ratio	irrig. freq. (days)	mar	Gross Irrigation Application (peak period ET/eff. in mm/day) apr	may	jun	jul	aug	sep	oct	season (mm/yr)
alfh	120	cor	45		6.14	7.68	9.33	9.22	7.87	6.32	4.38		2.70	1.10	6.7		15.01	18.77	22.81	22.54	19.24	15.45	10.66	
alfh	160	spr	65		6.14	7.68	9.33	9.22	7.87	6.32	4.36		2.70	1.10	6.7		10.39	13.00	15.79	15.60	13.32	10.70	7.38	
beans	40	fur	35			2.31	3.61	7.96	5.45	0.87			1.40	1.13	4.0			7.46	11.66	25.70	17.60	2.81		
Summary	320																10.82	14.47	17.90	19.47	16.07	11.49	7.69	

Peak Gross Irrigation Application (mm/day) =	19.47
On-Farm Irrigation Requirement (cfs/acre) =	0.032
Total On-Farm Irrigation Requirement (cfs) =	10.30
Irrigation Diversion Volume (ft/yr) =	0.00
Total Irrigation Diversion Volume (ac-ft/yr) =	0

adjustment is to divide the results of the field irrigation requirement equation by the ratio of actual operation time (in hours per day) to 24 hours per day. For use in the spreadsheet, the most convenient adjustment is to multiply the FAE by the ratio described above.

The appropriate ratio should be based on the actual number of sets irrigated per day for a particular system. There are normally one, two, or three sets per day for hand move sprinkler systems. This will depend on the number of sprinkler lines in a field and the required irrigation frequency. A standard quarter-mile hand move sprinkler line typically takes about one-half hour to move. A ratio of 0.94 (22.5 divided by 24) would be used for a system with three sets per day requiring one-half hour per set to move.

CONVEYANCE LOSS

Conveyance loss is the loss of water during transport from the point of diversion (at the source) to the place of use on the farm. Losses are due to seepage through the soil, leakage through headgates and other structures, evaporation from the water surface, and transpiration from plants growing in or near the channel. These losses can all be controlled to some extent, but cost may be prohibitive in many cases.

Seepage losses through the soil are dependent on the soil texture of the channel bed material but other factors can influence the seepage rate. Silt and sediment carried in the water will often reduce the seepage rate over time. A high water table can also affect the seepage rate of a channel. Seepage losses can be controlled by lining the channel or conveying the water through pipelines. Due to the high costs, channel lining or pipelines are not considered practical except in cases of extremely high losses in short reaches of a channel.

Conveyance losses due to leakage through headgates, valves, or other structures can be controlled through proper maintenance. Losses through evaporation are considered insignificant, especially when compared to the other types of losses that can occur. Transpiration from plants growing in or near the channel can cause high water losses. Plants growing in a channel can also restrict the flow and reduce the capacity of a channel. This causes higher seepage losses due to an increase in the wetted surface area of the channel. Losses due to plant growth should be minimized by removing plants through regular maintenance.

Since seepage losses are the primary losses that are the least practical to control, they must be quantified to determine the necessity of any additional water which may be required to overcome those losses for irrigation purposes. Seepage losses are usually highest when water is first turned into irrigation canals and ditches at the beginning of the irrigation season. Later in the season, when the demand for water is highest, the seepage rate will be relatively constant unless there are significant changes due to other factors. These factors may include changes in the water table, increased plant growth, or changes to the channel bed during removal of plant material or excess sediment.

The seepage losses in a canal can be measured by various methods. These methods can be difficult and/or costly and the expected level of accuracy does not warrant use of these methods in most circumstances. Measured values may also reflect a poor level of maintenance on a canal.

Seepage losses can be estimated for irrigation canals based on the seepage rate of the soil and the surface area of the soil where seepage occurs. The Hubble report guidelines suggest several formulas which can be used to estimate seepage losses. Each of these methods requires an estimation of the seepage rate of the canal material, the wetted perimeter of the canal, and the length of the canal. The seepage rate is usually expressed as cubic feet of water lost per square foot of soil surface per day. The seepage rate is multiplied by the wetted perimeter of the canal (in feet) and then converted to units of cfs per mile. The result is multiplied by the canal length (in miles) to obtain the total loss in cfs.

In 1975, IDWR compared several seepage loss estimation formulas to actual measured losses in two reaches of a canal (see Appendix I). Three of the seepage loss estimation formulas used in the study are given in the Hubble report guidelines (pages 36-38). The estimated losses calculated using those formulas compared well with the measured losses especially when higher estimates of soil seepage rates were used in the formulas. It was determined that all of the formulas would give similar results.

The seepage loss estimation procedure most commonly used by IDWR is shown on page 38 of the Hubble report guidelines as the Worstell method. This method requires an estimation of the soil seepage rate, measurements of the top width of the water surface at various points along the canal, and the canal length. The formula used is shown below:

$$S = 0.0667 \times (i) \times (W)$$

where:

S	=	seepage loss in cfs/mile
i	=	seepage rate in ft/day
W	=	top width of water surface in ft
0.0667	=	factor to estimate the wetted perimeter as a function of W and to convert units

The seepage loss estimated from the equation is multiplied by the canal length (miles) to obtain the total conveyance loss for the canal.

To estimate the soil seepage rate in the canal, NRCS soil survey maps and data can be used to identify the dominant soil texture for the soil layers penetrated by the canal. The tables on page 35 of the Hubble report guidelines can be used to choose the appropriate seepage rate based on the soil texture identified. Where a range of values is given, the higher values should be selected because, based on past studies, they give better results when compared to actual measurements.

In some cases, it may be possible to estimate the seepage rate in a canal by direct measurement of the conveyance losses in a representative section of the canal. The flow rate in the canal is measured at each end of the section, then the conveyance loss is obtained by calculating the difference between the two flow measurements. The conveyance loss is converted to a loss per mile value by dividing by the length (miles) of the section. The seepage rate is calculated by substituting the known values of seepage loss and canal top width into the Worstell equation and solving for the seepage rate. This seepage rate can be applied to the remainder of the canal. This approach may be reasonable if the conditions along the entire canal are relatively uniform and the measured reach is properly maintained.

The top width of the canal is measured across the canal along the water surface or at the high water marks of the canal. Several representative measurements should be taken along the canal length and averaged together. The canal length can be determined from maps and aerial photography.

In many cases, significant changes in soil textures or canal dimensions will occur along the length of a canal. Also, a canal may have several delivery points along its length if it is shared by many water users. In these cases, it is necessary to analyze each section or reach separately. The canal is divided into reaches based on the location of soil changes, canal dimension changes, or delivery points. The seepage losses are calculated for each reach and added together to obtain the total losses in the canal. In the case of several water users, the losses can be prorated among all the users based on the size and location of their deliveries.

IDWR has developed a computer spreadsheet to simplify the calculations required to determine conveyance losses on a canal with multiple water users (see Figure 14). The spreadsheet requires input of the length (feet), average width (feet), seepage rate (ft per day), and delivery amount (cfs) for each reach of the canal. The delivery amount is based on the amount of water required at the end of a reach which is delivered to lateral canals to satisfy the on-farm requirements plus any conveyance losses in the lateral canals.

The spreadsheet calculates the total loss for each reach and the losses to be assigned to the water users at each delivery point. The losses are assigned based on the size of the deliveries in each reach and the location of the deliveries on the canal. If there are several deliveries to individual water users at one delivery point, the delivery losses are prorated among those water users based on the size of their individual deliveries.

The example shown in Figure 14 has four separate reaches. Farms A and B are delivered water at the end of reach 1. Farms C and D are delivered water at the end of reaches 3 and 4 respectively. The canal was divided for analysis between reaches 2 and 3 because of a change in the average width and the soil seepage rate. There are no deliveries assigned in reach 2. The delivery losses assigned to farms C and D are shown under the heading "DELIVERY LOSS" as 0.74 cfs and 1.16 cfs respectively. Farms A and B share the delivery loss shown at the end of reach 1 (0.37 cfs) based on the sizes of their individual deliveries.

IRRIGATION DIVERSION RATE

The irrigation diversion rate is calculated by adding the on-farm irrigation requirement to the conveyance losses. This is the total diversion rate necessary, measured at the point of diversion from the source.

The irrigation diversion rate determined using the methodology described in this report is the amount reasonably necessary for an irrigation system based on acceptable irrigation practices. Since the diversion rate is based on an 80th percentile value of peak period ET for the historical cropping pattern with the highest diversion requirements, it should be recognized that the diversion rate will not be necessary every year or even throughout an entire irrigation season in a single year. If the actual capacity of an irrigation system is less than the irrigation diversion rate determined using the methodology described in this report, then the irrigation diversion rate recommended may need to be limited to the actual irrigation system capacity.

CONVEYANCE LOSS - WORSTELL

NAME OF DITCH: SAMPLE DITCH BY: JP DATE. 03/01/94

REACH	LENGTH (FT)	AVE WIDTH (FT)	SEEPAGE (FT/DAY)	WORSTEL LOSS (CFS)	DELIVERY (CFS)	DELIVERY LEFT (CFS)	LOSS FACTOR	DELIVERY LOSS (CFS)	FLOW (CFS)
1	2600	12.0	2.00	0.79	6.82	14.60	0.0540	0.37	16.86
2	1900	12.0	2.00	0.58	0.00	7.78	0.0740	0.00	9.26
3	2500	11.0	1.50	0.52	3.78	7.78	0.0670	0.74	8.68
4	1500	10.0	2.00	0.38	4.00	4.00	0.0947	1.16	4.38
5				0.00		0.00	0.0000	0.00	0.00
6				0.00		0.00	0.0000	0.00	0.00
7				0.00		0.00	0.0000	0.00	0.00
8				0.00		0.00	0.0000	0.00	0.00
9				0.00		0.00	0.0000	0.00	0.00
10				0.00		0.00	0.0000	0.00	0.00
11				0.00		0.00	0.0000	0.00	0.00
12				0.00		0.00	0.0000	0.00	0.00
13				0.00		0.00	0.0000	0.00	0.00
14				0.00		0.00	0.0000	0.00	0.00
15				0.00		0.00	0.0000	0.00	0.00
16				0.00		0.00	0.0000	0.00	0.00
17				0.00		0.00	0.0000	0.00	0.00
18				0.00		0.00	0.0000	0.00	0.00
19				0.00		0.00	0.0000	0.00	0.00
20				0.00		0.00	0.0000	0.00	0.00
TOTALS	8500			2.26	14.60			2.26	

REACH = SECTION OF CHANNEL
LENGTH = LENGTH OF REACH, THE CHANNEL CAN BE DIVIDED INTO EQUAL LENGTH REACHES OR ACTUAL LENGTHS BETWEEN DELIVERY POINTS
AVE WIDTH = AVERAGE TOP WIDTH OF WATER SURFACE IN REACH
SEEPAGE = SOIL SEEPAGE RATE OF REACH
WORSTELL LOSS = CONVEYANCE LOSS IN REACH BASED ON WORSTELL METHOD
DELIVERY = TOTAL DELIVERIES IN REACH
DELIVERY LEFT = SUM(DELIVERIES OF CURRENT AND REMAINING REACHES)
LOSS FACTOR = WORSTELL LOSS/DELIVERY LEFT
DELIVERY LOSS = SUM(LOSS FACTORS OF CURRENT AND PREVIOUS REACHES) X DELIVERY;
REPRESENTS THE LOSSES ASSIGNED TO THE DELIVERIES IN THE REACH;
IF MULTIPLE RIGHTS WITHIN REACH, DELIVERY LOSSES SHOULD BE PRORATED BASED ON SIZE OF DELIVERY FOR EACH RIGHT WITHIN REACH
FLOW = TOTAL FLOW AT BEGINNING OF EACH REACH

$S = 0.0667\, wi$ in cfs/mile

w = top width of water surface (ft)

i = ft/day

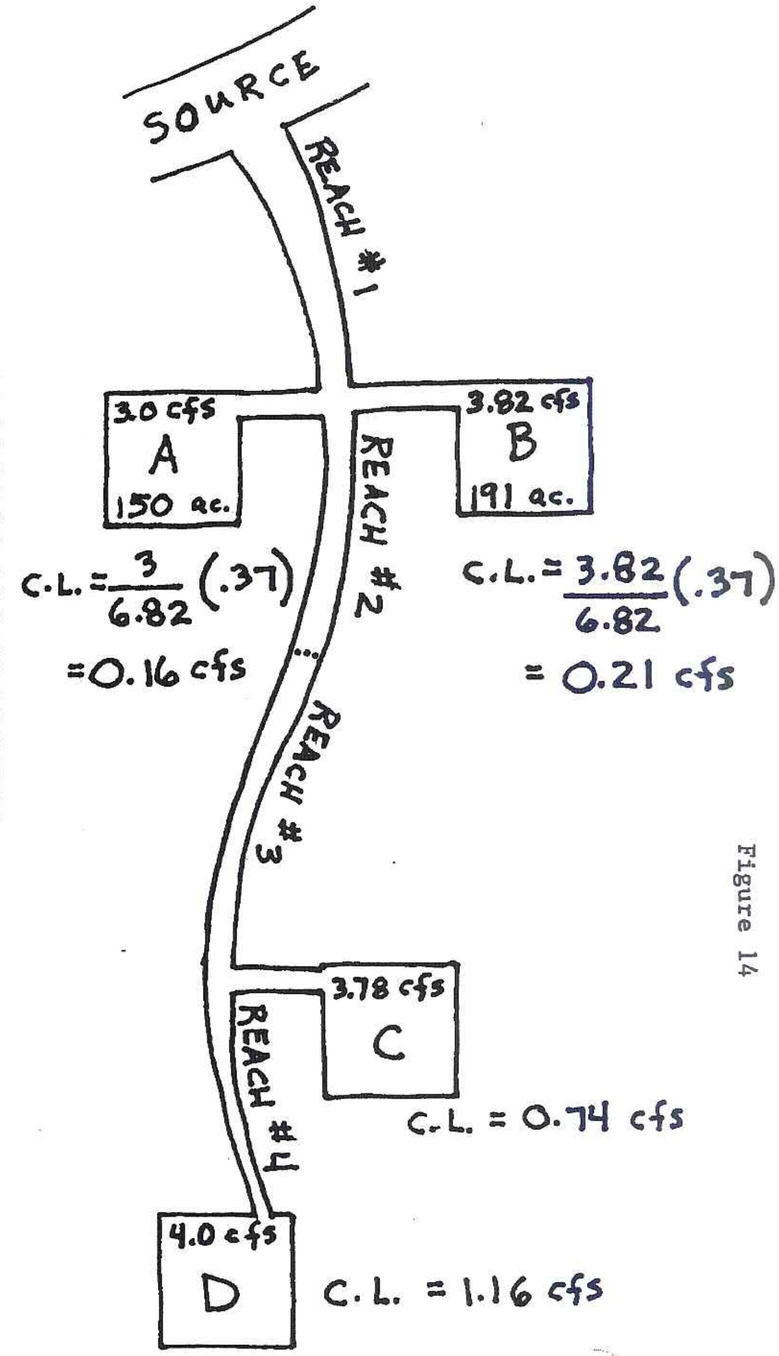

Figure 14

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CLOSING REMARKS

This report does not cover every conceivable condition that may be encountered when evaluating the necessity of a particular irrigation diversion rate. There may be unforeseen or special circumstances that require different or additional methods for evaluation.

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LIST OF APPENDIXES

APPENDIX A

Allen and Brockway ET Estimate
Sample Output

Est. CU and CIR.   Bliss   (Allen & Brockway,1983)   mm/day and mm/season

	MO	NYRS	PREC	ETR	ALFH.	BEANS	F.CRN	SILGE	S.CRN	PEAS	POTAT	SBEET	SGRAN	WGRAN	PAST.	VEGES
AVE ET	3	46	.87	2.14										.98		
AVE IR	3	46	100.00											.56		
STDD ET	3	46	.68	.35										.16		
STDD IR	3	46	100.00											.34		
SKEW ET	3	46	1.44	-.00										-.00		
SKEW IR	3	46	100.00											-1.26		
AVE ET	4	47	.72	5.28	3.30					1.60	1.58	1.58	1.65	4.82	3.27	
AVE IR	4	47	100.00		2.86					1.25	1.29	1.20	1.31	4.37	2.85	
STDD ET	4	47	.59	.47	.29					.14	.14	.14	.15	.43	.29	
STDD IR	4	47	100.00		.57					.39	.34	.42	.38	.69	.55	
SKEW ET	4	47	1.18	.20	.20					.20	.20	.20	.20	.20	.20	
SKEW IR	4	47	100.00		-.39					-.61	-.54	-.65	-.59	-.22	-.38	
AVE ET	5	47	.87	6.79	6.29	2.04	2.04	2.04	2.04	3.85	2.19	2.04	5.11	6.79	5.23	2.07
AVE IR	5	47	95.74		5.68	1.64	1.59	1.59	1.59	3.39	1.85	1.59	4.62	6.20	4.68	1.73
STDD ET	5	47	.65	.49	.46	.15	.15	.15	.15	.28	.16	.15	.37	.49	.38	.15
STDD IR	5	47	95.74		.77	.40	.43	.43	.43	.53	.37	.44	.62	.78	.67	.36
SKEW ET	5	47	1.16	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24
SKEW IR	5	47	95.74		-.42	-.72	-.74	-.74	-.74	-.53	-.65	-.75	-.42	-.36	-.46	-.67
AVE ET	6	47	.84	8.41	7.32	3.26	3.66	3.66	3.53	6.82	5.77	3.91	8.39	8.41	6.47	4.40
AVE IR	6	47	91.49		6.72	2.86	3.20	3.20	3.07	6.30	5.36	3.43	7.83	7.81	5.92	4.03
STDD ET	6	47	.82	.47	.41	.18	.21	.21	.20	.38	.32	.22	.47	.47	.36	.25
STDD IR	6	47	91.49		.89	.53	.61	.61	.60	.78	.63	.63	.89	.93	.80	.54
SKEW ET	6	47	.99	.64	.63	.63	.63	.63	.63	.61	.64	.62	.62	.64	.63	.62
SKEW IR	6	47	91.49		-.31	-.55	-.56	-.56	-.58	-.25	-.20	-.55	-.15	-.21	-.33	-.33
AVE ET	7	47	.30	8.54	6.94	7.37	7.68	7.68	7.47	2.99	7.17	8.14	7.05	6.80	6.57	6.57
AVE IR	7	47	72.34		6.79	7.24	7.53	7.53	7.32	2.89	7.06	7.98	6.92	6.67	6.44	6.47
STDD ET	7	47	.32	.26	.21	.23	.24	.24	.23	.09	.22	.25	.22	.21	.20	.20
STDD IR	7	47	72.34		.37	.35	.38	.38	.38	.21	.32	.40	.34	.35	.34	.30
SKEW ET	7	47	2.40	.05	-.02	-.03	-.04	-.04	-.03	.03	.02	-.11	.02	-.04	.02	.03
SKEW IR	7	47	72.34		-1.55	-1.32	-1.44	-1.44	-1.45	-2.06	-1.17	-1.44	-1.35	-1.48	-1.54	-1.22
AVE ET	8	46	.37	7.18	5.41	4.97	6.63	6.63	6.38		5.57	7.06	1.47	1.32	5.53	5.72
AVE IR	8	46	65.22		5.27	4.85	6.48	6.48	6.23		5.46	6.90	1.37	1.21	5.39	5.61
STDD ET	8	46	.60	.33	.25	.23	.30	.30	.29		.26	.32	.07	.06	.25	.26
STDD IR	8	46	65.22		.51	.44	.57	.57	.55		.44	.60	.27	.28	.50	.45
SKEW ET	8	46	3.27	.24	.25	.23	.22	.22	.25		.25	.26	.25	.24	.25	.25
SKEW IR	8	46	65.22		-2.46	-2.33	-2.21	-2.21	-2.25		-1.98	-2.18	-3.38	-3.47	-2.38	-1.95
AVE ET	9	46	.49	5.60	3.67	.77	4.19	4.19			3.29	4.86			4.32	3.83
AVE IR	9	46	78.26		3.44	.61	3.97	3.97			3.12	4.62			4.09	3.65
STDD ET	9	46	.60	.41	.27	.06	.31	.31			.24	.36			.32	.28
STDD IR	9	46	78.26		.49	.28	.52	.52			.39	.57			.53	.43
SKEW ET	9	46	1.75	-.34	-.34	-.34	-.34	-.34			-.34	-.34			-.34	-.34
SKEW IR	9	46	78.26		-1.04	-1.75	-.93	-.93			-.88	-.86			-.91	-.79
AVE ET	10	47	.61	3.73	1.26		1.04					2.48			2.88	
AVE IR	10	47	95.74		.96		.76					2.17			2.56	
STDD ET	10	47	.61	.35	.12		.10					.24			.27	
STDD IR	10	47	95.74		.39		.36					.48			.51	
SKEW ET	10	47	1.84	-.04	-.04		-.04					-.04			-.04	
SKEW IR	10	47	95.74		-1.32		-1.37					-.98			-.89	
AVE ET	SE	45	118.5	1457.	1044.	566.	774.	742.	598.	464.	781.	921.	722.	888.	1047.	692.
AVE IR	SE	45	0.0	0.	968.	529.	721.	698.	561.	420.	738.	854.	673.	817.	975.	658.
STDD ET	SE	45	42.9	43.	30.	15.	20.	19.	16.	17.	21.	23.	23.	31.	29.	18.
STDD IR	SE	45	0.0	0.	54.	31.	36.	38.	34.	39.	39.	45.	46.	58.	51.	32.
SKEW ET	SE	45	.30	.08	.29	.15	.08	.03	.20	.33	.22	.09	.34	.25	.20	.08
SKEW IR	SE	45			-.05	-.54	-.30	-.47	-.50	-.29	-.26	-.30	-.12	-.12	-.12	-.33

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APPENDIX B

IDWR Adjudication Memorandum #42

ADJUDICATION MEMO #42

To: Adjudication Staff
From: Jeff Peppersack
Date: May 5, 1995

Approved: NCY *NCY*
DBS *DBS*

Re: Irrigation Diversion Rate Calculations - Peak Consumptive Use

This memo is notification of a change in our standard procedure to calculate irrigation diversion rates as described in the EVALUATION WORKBOOK FOR IRRIGATION DIVERSION RATES and GUIDELINES FOR THE EVALUATION OF IRRIGATION DIVERSION RATES by Hubble Engineering, Inc. and Associated Earth Sciences Inc. This change will affect the application of consumptive use values from the Allen and Brockway tables.

The design capacity of an irrigation system is generally based on the peak consumptive use of the expected cropping pattern for the period between irrigations. Since peak consumptive use data is not widely available for crops in Idaho, the Hubble workbook and guidelines direct you to use average monthly consumptive use values for the most water consumptive crop in the area or in the rotation. This method may underestimate diversion requirements, especially in cases where a single crop is grown.

A method of estimating peak consumptive use rates from monthly estimates is available from the ASAE publication entitled, DESIGN AND OPERATION OF FARM IRRIGATION SYSTEMS by Marvin Jensen, 1983. The table below was derived from Figure 6.6 (page 223) of that publication. These table values will be used in conjunction with the Allen and Brockway consumptive use tables.

Estimating Peak Consumptive Use From Monthly Estimates

Irrigation Application Depth (in)	Ratio of Peak CU to Monthly CU
1	1.14
2	1.11
3	1.09
4	1.07
5	1.05
6	1.04
7	1.03
8	1.02

Irrigation application depth, the amount applied during an irrigation, is calculated for each crop using Table 4 in the Hubble workbook.

Table 1 in the Hubble workbook requires input of the crop's "AVE IR", for each month, from the Allen and Brockway tables. The "AVE IR" represents the average monthly consumptive irrigation requirement for each crop. The monthly values should be multiplied by the appropriate ratio from the table above. The results are estimates of the crop's peak consumptive irrigation requirement for each month. These values are entered into Table 1 of the Hubble workbook. This must be done for the most water-consumptive cropping pattern, or mix of crops in the crop rotation, instead of just the most water consumptive crop as was done in the past.

Example: A farmer in Aberdeen grows grain and alfalfa hay on a 100-acre farm. The crop rotation practiced never allows more than 75 acres of either crop in any given year. From Table 4 in the Hubble workbook you calculate a MAD (irrigation application depth) of 2.4 inches for the grain and 3.1 inches for the alfalfa. From the table above you choose a ratio of 1.11 for the grain and 1.09 for the alfalfa. The attached sheets show the calculations using the Allen and Brockway table for the Aberdeen station and the entries into Table 1 of the Hubble workbook.

EXAMPLE

PEAK CONSUMPTIVE IRRIGATION REQUIREMENT:

(AVE IR)(RATIO) = PEAK CIR

Est. CU and CIR.   Aberdeen Exp. Station   (Allen & Brockway, 1983)   mm/day and mm/season

		MO	NYRS	PREC	ETR	ALFN.	ALFS.	BEANS	SILGE	S.CRN	PEAS	POTAT	SBEET	SGRAN	WGRAN	PAST.	VEGES
	AVE ET	3	49	.70	1.56										.52		
	AVE IR	3	49	100.00											.20		
	STDD ET	3	49	.57	.47										.16		
	STDD IR	3	49	100.00											.29		
	SKEW ET	3	49	1.93	-.41										-.41		
	SKEW IR	3	49	100.00											-.76		
APR	AVE ET	4	49	.83	4.36	2.22	2.75				1.31		1.31	1.31	3.42	2.35	
	AVE IR	4	49	100.00		1.74	2.25				.91		.06	.92	2.94	1.88	
	STDD ET	4	49	.58	.54	.28	.34				.16		.16	.16	.43	.29	
	STDD IR	4	49	100.00		.52	.58				.38		.41	.30	.64	.52	
	SKEW ET	4	49	.75	-.00	-.00	-.00				-.00		-.00	-.00	-.00	-.00	
	SKEW IR	4	49	100.00		-.18	-.13				-.29		-.32	-.28	-.86	-.16	
MAY	AVE ET	5	48	1.08	6.01	5.55	5.39		1.80	1.80	2.76	1.82	1.80	3.45	5.97	4.63	1.82
	AVE IR	5	48	97.92		4.82	4.66		1.25	1.25	2.22	1.40	1.24	2.90	5.27	3.96	1.40
	STDD ET	5	48	.68	.91	.48	.46		.15	.15	.24	.16	.19	.30	.51	.40	.16
	STDD IR	5	48	97.92		.83	.81		.47	.47	.52	.39	.47	.57	.84	.72	.39
	SKEW ET	5	48	.36	.36	.36	.35		.35	.35	.35	.55	.35	.36	.36	.36	.36
	SKEW IR	5	48	97.92		.36	.35		.15	.15	.26	.22	.15	.51	.38	.54	.22
JUN	AVE ET	6	49	.93	7.96	6.99	7.03	2.60	2.76	2.70	6.74	4.93	3.37	7.81	7.96	6.13	4.08
	AVE IR	6	49	100.00		6.26	6.30	2.21	2.23	2.17	6.11	4.46	2.81	7.16	7.24	5.47	3.63
	STDD ET	6	49	.89	.48	.42	.42	.16	.17	.16	.40	.30	.20	.47	.48	.37	.24
	STDD IR	6	49	100.00		.91	.91	.52	.57	.57	.82	.61	.62	.89	.94	.81	.55
	SKEW ET	6	49	2.85	.40	.39	.40	.40	.39	.39	.39	.39	.40	.40	.40	.40	.39
	SKEW IR	6	49	100.00		-1.29	-1.29	-1.72	-1.77	-1.78	-1.20	-1.23	-1.68	-1.09	-1.16	-1.33	-1.36
JUL	AVE ET	7	49	.42	8.37	6.85	6.28	6.64	6.73	6.52	3.64	7.03	7.75	8.08	7.99	6.45	6.41
	AVE IR	7	49	87.76		6.58	6.02	6.42	6.48	6.27	3.45	6.83	7.48	7.83	7.72	6.20	6.32
	STDD ET	7	49	.42	.32	.26	.24	.26	.26	.25	.14	.27	.30	.31	.31	.25	.25
	STDD IR	7	49	87.76		.45	.43	.40	.44	.43	.29	.39	.48	.47	.48	.42	.36
	SKEW ET	7	49	1.47	.05	.04	.04	.05	.04	.05	.04	.04	.04	.06	.03	.05	.03
	SKEW IR	7	49	87.76		-1.00	-1.03	-.92	-.97	-.99	-1.16	-.82	-.97	-.85	-.90	-.99	-.85
AUG	AVE ET	8	49	.46	6.74	5.10	3.16	5.33	6.35	6.16		5.29	6.86	2.29	2.02	5.19	5.37
	AVE IR	8	49	97.96		4.82	2.91	5.08	6.05	5.87		5.08	6.35	2.08	1.81	4.92	5.16
	STDD ET	8	49	.60	.31	.24	.15	.25	.30	.29		.25	.31	.11	.09	.24	.25
	STDD IR	8	49	97.96		.54	.44	.51	.60	.59		.46	.63	.35	.38	.53	.47
	SKEW ET	8	49	3.62	-.75	-.76	-.78	-.77	-.75	-.74		-.74	-.74	-.75	-.75	-.75	-.74
	SKEW IR	8	49	97.96		-2.80	-3.08	-2.69	-2.67	-2.68		-2.58	-2.66	-3.06	-3.10	-2.77	-2.57
SEP	AVE ET	9	49	.61	5.00	3.31	1.62	.89	4.11			3.09	4.41			3.85	3.44
	AVE IR	9	49	91.84		2.97	1.35	.64	3.78			2.84	4.06			3.52	3.19
	STDD ET	9	49	.66	.40	.27	.13	.07	.33			.25	.36			.31	[illegible]
	STDD IR	9	49	91.84		.56	.45	.33	.61			.45	.64			.59	[illegible]
	SKEW ET	9	49	2.18	-.58	-.58	-.58	-.58	-.58			-.50	-.58			-.58	-.58
	SKEW IR	9	49	91.84		-1.01	-1.34	-1.52	-.89			-.87	-.07			-.91	-.83
OCT	AVE ET	10	48	.83	3.20	1.09	.55						2.22			2.46	
	AVE IR	10	48	95.83		.68	.16						1.79			2.03	
	STDD ET	10	48	.70	.36	.12	.06						.25			.28	
	STDD IR	10	48	95.83		.41	.37						.49			.50	
	SKEW ET	10	48	1.49	-.49	-.49	-.49						-.49			-.49	
	SKEW IR	10	48	95.83		-.75	-.97						-.40			-.35	
	AVE ET	SE	47	144.4	1323.	952.	819.	478.	668.	530.	441.	679.	844.	703.	854.	951.	847.
	AVE IR	SE	47	0.0	0.	854.	723.	442.	600.	400.	388.	632.	754.	641.	772.	857.	801.
	STDD ET	SE	47	51.3	60.	38.	35.	16.	24.	10.	19.	24.	52.	27.	39.	39.	23.
	STDD IR	SE	47	0.0	0.	63.	59.	29.	42.	35.	40.	37.	55.	48.	62.	62.	37.
	SKEW ET	SE	47	.60	-.06	-.08	.05	-.18	-.53	-.04	.18	-.37	-.33	.21	.31	-.18	-.45
	SKEW IR	SE	47			-.43	-.42	-.80	-.88	-.73	-.74	-.77	-.52	-.50	-.16	-.41	-.80

	ALFALFA	S. GRAIN
APR	(1.74)(1.09) = 1.90	(0.92)(1.11) = 1.02
MAY	(4.82)(1.09) = 5.25	(2.90)(1.11) = 3.22
JUN	(6.26)(1.09) = 6.82	(7.16)(1.11) = 7.95
JUL	(6.58)(1.09) = 7.17	(7.83)(1.11) = 8.69
AUG	(4.82)(1.09) = 5.25	(2.08)(1.11) = 2.31
SEP	(2.97)(1.09) = 3.24	
OCT	(0.68)(1.09) = 0.74	

A&B 1409

SNAKE RIVEI ADJUDICA IION
FIELD IRRIGA N REQUIRMENT

TECH: ______ DATE: 17/95

WEATHER STATION: ABERDEEN CLAIMANT: EXAMPLE ID NO. ______

	ACREAGE		TYP	IRR	NET IRRIGATION REQUIREMENT								
CROP	ACRES	%	IRR	EFF %	MAR MM/DAY	APR MM/DAY	MAY MM/DAY	JUN MM/DAY	JUL MM/DAY	AUG MM/DAY	SEP MM/DAY	OCT MM/DAY	SEASON MM/SEA
ALFH.	120	38	COR	30		3.10	5.25	6.25	6.99	5.27	3.49	0.78	950
ALFH.	160	50	SPR	65		3.10	5.25	6.25	6.99	5.27	3.49	0.78	950
SBEET	40	13	FUR	35		0.96	1.46	3.67	8.45	6.82	4.39	1.55	835
SUMMARY	320	100		48		2.83	4.78	5.94	7.17	5.46	3.60	0.88	936
ALFH	25	25				1.90	5.25	6.82	7.17	5.25	3.24	0.74	854
SGRN	75	75				1.02	3.22	7.95	8.69	2.31	—	—	641
SUMMARY	100	100				1.24	3.73	7.67	8.31	3.05	0.81	0.19	694
SUMMARY													

LARGEST SUMMARY MONTHLY VALUE ______, DIVIDE BY SUMMARY IRR. EFF. = ______ MM/DAY, MULTIPLY BY 0.001657 = ______ CFS/ACRE FIELD

CFS/AC MULTIPLY BY SUMMARY ACRES = CFS FIELD REQUIREMENT. ADD

A&B 1410

APPENDIX C

Estimate of Peak Period ET
Using Monthly ET Estimate
Example

U. S. Bureau of Reclamation
Pacific Northwest Region
Boise-Minidoka HYDROMET/AGRIMET System

TWFI - ET SUMMARY - 1992

DATE	10 ALFP	11 ALFM	12 PAST	21 WGRN	22 SGRN	23 SGRN	31 BEET	35 ONYN	41 POTA	42 POTA	51 BEAN	61 FCRN	66 SCRN	91 APPL
701	0.23	0.20	0.16	0.17	0.23	0.23	0.22	0.23	0.21	0.20	0.22	0.19	0.19	0.22
702	0.28	0.24	0.19	0.20	0.28	0.28	0.27	0.28	0.26	0.25	0.27	0.23	0.23	0.27
703	0.24	0.20	0.16	0.17	0.24	0.24	0.24	0.24	0.22	0.22	0.23	0.20	0.20	0.23
704	0.25	0.21	0.17	0.17	0.25	0.25	0.25	0.25	0.23	0.23	0.24	0.21	0.21	0.24
705	0.31	0.26	0.21	0.20	0.31	0.31	0.31	0.31	0.29	0.28	0.29	0.27	0.27	0.30
706	0.29	0.25	0.20	0.18	0.29	0.29	0.29	0.29	0.27	0.26	0.28	0.26	0.26	0.28
707	0.32	0.27	0.22	0.19	0.31	0.32	0.32	0.32	0.30	0.29	0.30	0.29	0.29	0.31
708	0.30	0.26	0.20	0.17	0.29	0.30	0.30	0.30	0.28	0.28	0.28	0.27	0.27	0.29
709	0.32	0.27	0.22	0.17	0.31	0.32	0.32	0.32	0.30	0.30	0.30	0.29	0.29	0.31
710	0.29	0.25	0.20	0.15	0.26	0.29	0.29	0.29	0.27	0.27	0.28	0.27	0.27	0.28
711	0.22	0.19	0.15	0.11	0.19	0.22	0.22	0.22	0.20	0.20	0.21	0.21	0.21	0.21
712	0.28	0.24	0.19	0.13	0.23	0.28	0.28	0.28	0.26	0.26	0.27	0.27	0.27	0.27
713	0.31	0.26	0.21	0.14	0.24	0.31	0.31	0.31	0.29	0.29	0.29	0.30	0.30	0.30
714	0.34	0.29	0.23	0.14	0.24	0.34	0.34	0.34	0.32	0.32	0.32	0.34	0.34	0.33
715	0.36	0.31	0.24	0.14	0.24	0.36	0.36	0.36	0.33	0.33	0.34	0.36	0.36	0.35
716	0.34	0.29	0.23	0.13	0.22	0.34	0.34	0.34	0.32	0.32	0.32	0.34	0.34	0.33
717	0.34	0.29	0.23	0.12	0.20	0.34	0.34	0.34	0.32	0.32	0.32	0.34	0.34	0.33
718	0.30	0.26	0.20	0.10	0.17	0.29	0.30	0.30	0.28	0.28	0.28	0.30	0.30	0.29
719	0.30	0.26	0.20	0.09	0.15	0.29	0.30	0.30	0.28	0.28	0.28	0.30	0.30	0.29
720	0.32	0.27	0.22	0.00	0.15	0.30	0.32	0.32	0.30	0.30	0.30	0.32	0.32	0.31
721	0.32	0.27	0.22	--	0.14	0.29	0.32	0.32	0.30	0.30	0.30	0.32	0.32	0.31
722	0.36	0.31	0.24	--	0.14	0.30	0.36	0.36	0.33	0.33	0.34	0.36	0.36	0.35
723	0.31	0.26	0.21	--	0.11	0.25	0.31	0.31	0.29	0.29	0.29	0.31	0.31	0.30
724	0.29	0.25	0.20	--	0.09	0.22	0.29	0.29	0.27	0.27	0.28	0.29	0.29	0.28
725	0.28	0.24	0.19	--	0.00	0.20	0.28	0.28	0.26	0.26	0.27	0.28	0.28	0.27
726	0.30	0.26	0.20	--	--	0.20	0.30	0.30	0.28	0.28	0.28	0.30	0.30	0.29
727	0.31	0.26	0.21	--	--	0.20	0.31	0.31	0.28	0.29	0.29	0.31	0.31	0.30
728	0.33	0.28	0.22	--	--	0.20	0.33	0.33	0.30	0.31	0.31	0.33	0.33	0.32
729	0.35	0.30	0.24	--	--	0.19	0.35	0.35	0.32	0.33	0.32	0.35	0.34	0.34
730	0.31	0.26	0.21	--	--	0.16	0.31	0.31	0.28	0.29	0.28	0.31	0.30	0.30
731	0.33	0.28	0.22	--	--	0.15	0.33	0.33	0.30	0.31	0.29	0.33	0.32	0.32

AVE = 0.29 in

EXAMPLE:

A 1" NET IRRIGATION APPLICATION FOR BEANS WILL PROVIDE WATER FOR ABOUT 3 DAYS BECAUSE DURING THE PEAK WATER-USE PERIOD (JULY 14, 15 + 16) THE CROP WILL USE ABOUT 1" OF WATER

(0.32 + 0.34 + 0.32 = 0.98 in)

THE AVERAGE USE FOR THE 3-DAY PERIOD IS 0.33 in.

APPLYING THE RATIO TO ESTIMATE THE PEAK PERIOD CROP ET FROM THE MONTHLY VALUE (FROM IDWR ADJ. MEMO #42)

0.29 in × 1.14 = 0.33 in.

APPENDIX D

Hagerman Valley Monthly ET Estimates

80th Percentile values of monthly ET estimated for
the Hagerman Valley adjusted from the Bliss Station
(mm/day)

	MO	ETR	ALFH.	BEANS	F.CRN	SILGE	S.CRN	PEAS	POTAT	SBEET	SGRAN	WGRAI	PAST.	VEGES
AVE ET	4	5.28	3.30					1.60	1.58	1.58	1.65	4.82	3.27	
TMP ADJ	4	5.68	3.55					1.72	1.70	1.70	1.77	5.18	3.52	
ALT ADJ	4	5.75	3.59					1.74	1.72	1.72	1.80	5.25	3.56	
STDD ET	4	0.47	0.29					0.14	0.14	0.14	0.15	0.43	0.29	
80PCT ET	4	6.14	3.84					1.86	1.84	1.84	1.92	5.61	3.80	
AVE ET	5	6.79	6.29	2.04	2.04	2.04	2.04	3.85	2.19	2.04	5.11	6.79	5.23	2.07
TMP ADJ	5	7.18	6.65	2.16	2.16	2.16	2.16	4.07	2.31	2.16	5.40	7.18	5.53	2.19
ALT ADJ	5	7.27	6.73	2.18	2.18	2.18	2.18	4.12	2.34	2.18	5.47	7.27	5.60	2.21
STDD ET	5	0.49	0.46	0.15	0.15	0.15	0.15	0.28	0.16	0.15	0.37	0.49	0.38	0.15
80PCT ET	5	7.68	7.12	2.31	2.31	2.31	2.31	4.36	2.48	2.31	5.78	7.68	5.92	2.34
AVE ET	6	8.41	7.32	3.26	3.66	3.66	3.53	6.82	5.77	3.91	8.39	8.41	6.47	4.40
TMP ADJ	6	8.82	7.68	3.42	3.84	3.84	3.70	7.15	6.05	4.10	8.80	8.82	6.79	4.62
ALT ADJ	6	8.93	7.77	3.46	3.89	3.89	3.75	7.24	6.13	4.15	8.91	8.93	6.87	4.67
STDD ET	6	0.47	0.41	0.18	0.21	0.21	0.20	0.38	0.32	0.22	0.47	0.47	0.36	0.25
80PCT ET	6	9.33	8.12	3.61	4.06	4.06	3.92	7.56	6.40	4.34	9.31	9.33	7.17	4.88
AVE ET	7	8.54	6.94	7.37	7.68	7.68	7.47	2.99	7.17	8.14	7.05	6.80	6.57	6.57
TMP ADJ	7	8.89	7.22	7.67	7.99	7.99	7.78	3.11	7.46	8.47	7.34	7.08	6.84	6.84
ALT ADJ	7	9.00	7.31	7.77	8.09	8.09	7.87	3.15	7.56	8.58	7.43	7.17	6.92	6.92
STDD ET	7	0.26	0.21	0.23	0.24	0.24	0.23	0.09	0.22	0.25	0.22	0.21	0.20	0.20
80PCT ET	7	9.22	7.49	7.96	8.30	8.30	8.07	3.23	7.74	8.79	7.61	7.34	7.09	7.09
AVE ET	8	7.18	5.41	4.97	6.63	6.63	6.38		5.57	7.06	1.47	1.32	5.53	5.72
TMP ADJ	8	7.50	5.65	5.19	6.92	6.92	6.66		5.82	7.37	1.53	1.38	5.77	5.97
ALT ADJ	8	7.59	5.72	5.25	7.01	7.01	6.74		5.89	7.46	1.55	1.40	5.84	6.05
STDD ET	8	0.33	0.25	0.23	0.30	0.30	0.29		0.26	0.32	0.07	0.06	0.25	0.26
80PCT ET	8	7.87	5.93	5.45	7.26	7.26	6.99		6.11	7.73	1.61	1.45	6.05	6.26
AVE ET	9	5.60	3.67	0.77	4.19	4.19			3.29	4.86			4.32	3.83
TMP ADJ	9	5.90	3.87	0.81	4.42	4.42			3.47	5.12			4.55	4.04
ALT ADJ	9	5.97	3.92	0.82	4.47	4.47			3.51	5.19			4.61	4.09
STDD ET	9	0.41	0.27	0.06	0.31	0.31			0.24	0.36			0.32	0.28
80PCT ET	9	6.32	4.14	0.87	4.73	4.73			3.71	5.49			4.88	4.32
AVE ET	10	3.73	1.26		1.04					2.48			2.88	
TMP ADJ	10	4.02	1.36		1.12					2.67			3.10	
ALT ADJ	10	4.07	1.37		1.13					2.70			3.14	
STDD ET	10	0.35	0.12		0.10					0.24			0.27	
80PCT ET	10	4.36	1.47		1.22					2.91			3.37	

ET and standard deviation data (AVE ET and STDD ET) for Bliss weather station taken from Appendix E (unpublished) of Brockway, C.E., and R.G. Allen, 1983, Estimating Consumptive Irrigation Requirements for Crops in Idaho, Idaho Water and Energy Resources Research Institute.

Temperature adjustment (TMP ADJ) based on temperature differences between Bliss and Hagerman and temperature sensitivity of ET estimates given in Brockway, C.E., G.S. Johnson, J.L. Wright, and A.L. Coiner, 1985, Remote Sensing for Irrigated Crop Water Use - Phase 1, Water Resources Research Institute, pp. 101-107.

Altitude adjustment (ALT ADJ) based on Doorenbos, J., and W.O. Pruitt, 1977, Crop Water Requirements, Food and Agriculture Organization of the United Nations, p. 59.

80th percentile ET values (80PCT ET) calculated based on Walpole, R.E., and R.H. Meyers, 1985, third edition, PROBABILITY AND STATISTICS FOR ENGINEERS AND SCIENTISTS, New York: Macmillan Publishing Company, pp. 132-144 and 574.

TEMPERATURE AND ELEVATION DATA FOR BLISS AND HAGERMAN

YEAR	1983	1985	1988	1989	1990
MAR/APR/MAY AVG. TEMP. FOR HAGERMAN	50.2	50.7	51.5	52.8	54.1
MAR/APR/MAY AVG. TEMP. FOR BLISS	48.5	47.7	50.6	52.4	52.3
TEMPERATURE DIFFERENCES	1.6	3.1	0.9	0.4	1.8
AVG. OF TEMP. DIFFERENCES	1.6				
ELEVATION OF HAGERMAN (FT.)	2875				
ELEVATION OF BLISS (FT.)	3280				
ELEVATION DIFFERENCE (FT.)	-405				

SOURCE OF INFORMATION: IDAHO STATE CLIMATOLOGIST
NOTE: ALL TEMPERATURES ARE IN DEGREES FAHRENHEIT

TEMPERATURE SENSITIVITY OF ET ESTIMATES FOR BLISS BASED ON A +1.6 DEGREE F. TEMPERATURE CHANGE

APRIL	+7.5%
MAY	+5.7%
JUNE	+4.9%
JULY	+4.1%
AUG	+4.4%
SEP	+5.4%
OCT	+7.7%

BLISS ET ESTIMATES BASED ON FAO-BC FROM ALLEN AND BROCKWAY, 1983
TEMPERATURE SENSITIVITY BASED ON BROCKWAY ET AL., 1985

ALTITUDE ADJUSTMENT FOR ET ESTIMATE FROM BLISS TO HAGERMAN

10% DECREASE FOR EACH 1000 M INCREASE IN ELEVATION

ELEVATION DIFFERENCE FROM BLISS TO HAGERMAN = -405 FT = -123.4 M

-10%/+1000 M * (-123.4 M) = +1.23%

80^{TH} PERCENTILE CALCULATIONS FOR HAGERMAN ET ESTIMATES

FOR NORMAL DISTRIBUTION

80^{TH} PCT ET = (Z * STDD) + AVE ET

Z = 0.842

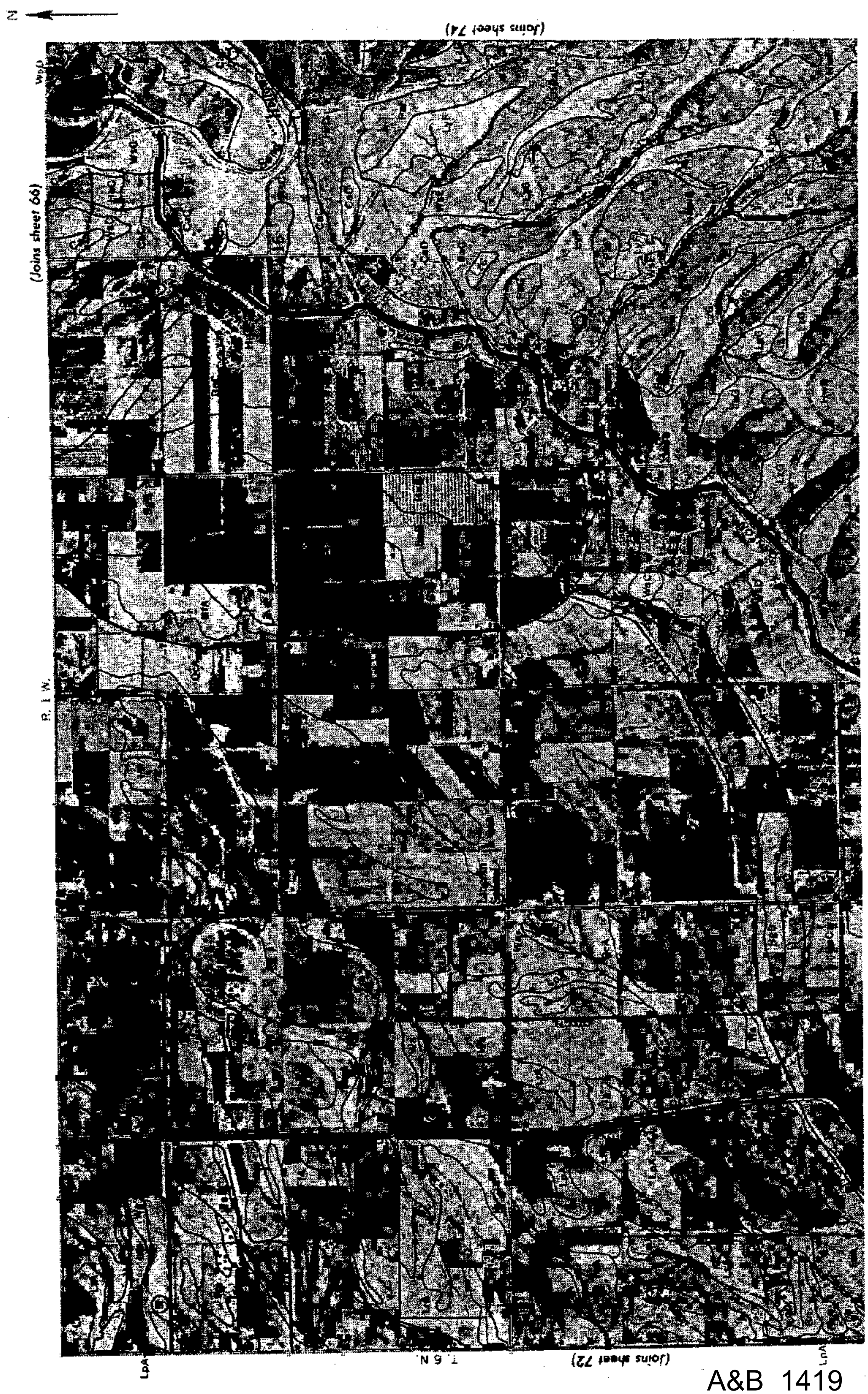
EXAMPLE FOR BEANS IN JULY:

(0.842 * 0.23) + 7.77 = 7.96 MM/DAY

APPENDIX E

NRCS Soil Map and Computer-Generated Tables

GEM COUNTY AREA, IDAHO — SHEET NUMBER 73



A&B 1419

Source: USDA, NRCS, 1965, Soil Survey, Gem County Area, Idaho

PHYSICAL AND CHEMICAL PROPERTIES OF THE SOILS

Survey Area- GEM COUNTY AREA, IDAHO

Map Symbol	Soil Name	Depth (In)	Clay (pct)	Moist Blk Density (g/cm3)	Permeab-ility (In/hr)	Available water cap (In/in)	Soil React (ph)	Salin-ity (mmhos/cm)	Shrink Swell Pot.	Erosion Factor K	Erosion Factor T	Wind Erod. Group	Organic Matter (pct)
		16-20	-	-	-	-	-	-					-
GwF	GWIN	0- 5	10-20	1.20-1.30	0.6- 2.0	0.08-0.11	6.6-7.3	-	LOW	.10	1	8	2.- 3.
		5-16	27-35	1.20-1.40	0.2- 0.6	0.07-0.11	6.6-7.3	-	LOW	.10			-
		16-20	-	-	-	-	-	-					-
GwG	GWIN	0- 5	10-20	1.20-1.30	0.6- 2.0	0.08-0.11	6.6-7.3	-	LOW	.10	1	8	2.- 3.
		5-16	27-35	1.20-1.40	0.2- 0.6	0.07-0.11	6.6-7.3	-	LOW	.10			-
		16-20	-	-	-	-	-	-					-
HaB	HARPT	0-10	8-12	1.60-1.70	2.0- 6.0	0.11-0.13	6.1-7.3	0- 2	LOW	.24	5	3	1.- 2.
		10-46	20-27	1.50-1.60	0.6- 2.0	0.16-0.21	6.1-7.8	0- 2	LOW	.37			-
		46-60	10-15	1.40-1.70	0.2- 0.6	0.13-0.18	6.1-7.8	0- 2	LOW	.28			-
HaC	HARPT	0-10	8-12	1.60-1.70	2.0- 6.0	0.11-0.13	6.1-7.3	0- 2	LOW	.24	5	3	1.- 2.
		10-46	20-27	1.50-1.60	0.6- 2.0	0.16-0.21	6.1-7.8	0- 2	LOW	.37			-
		46-60	10-15	1.40-1.70	0.2- 0.6	0.13-0.18	6.1-7.8	0- 2	LOW	.28			-
HaD	HARPT	0-10	8-12	1.60-1.70	2.0- 6.0	0.11-0.13	6.1-7.3	0- 2	LOW	.24	5	3	1.- 2.
		10-46	20-27	1.50-1.60	0.6- 2.0	0.16-0.21	6.1-7.8	0- 2	LOW	.37			-
		46-60	10-15	1.40-1.70	0.2- 0.6	0.13-0.18	6.1-7.8	0- 2	LOW	.28			-
HaE	HARPT	0-10	8-12	1.60-1.70	2.0- 6.0	0.11-0.13	6.1-7.3	0- 2	LOW	.24	5	3	1.- 2.
		10-46	20-27	1.50-1.60	0.6- 2.0	0.16-0.21	6.1-7.8	0- 2	LOW	.37			-
		46-60	10-15	1.40-1.70	0.2- 0.6	0.13-0.18	6.1-7.8	0- 2	LOW	.28			-
[illegible]	HARPT	0-10	12-22	1.50-1.60	0.6- 2.0	0.16-0.18	6.1-7.3	0- 2	LOW	.32	5	5	1.- 2.
		10-46	20-27	1.50-1.60	0.6- 2.0	0.16-0.21	6.1-7.8	0- 2	LOW	.37			-
		46-60	10-15	1.40-1.70	0.2- 0.6	0.13-0.18	6.1-7.8	0- 2	LOW	.28			-
HrB	HARPT	0-10	12-22	1.50-1.60	0.6- 2.0	0.16-0.18	6.1-7.3	0- 2	LOW	.32	5	5	1.- 2.
		10-46	20-27	1.50-1.60	0.6- 2.0	0.16-0.21	6.1-7.8	0- 2	LOW	.37			-
		46-60	10-15	1.40-1.70	0.2- 0.6	0.13-0.18	6.1-7.8	0- 2	LOW	.28			-
HrC	HARPT	0-10	12-22	1.50-1.60	0.6- 2.0	0.16-0.18	6.1-7.3	0- 2	LOW	.32	5	5	1.- 2.
		10-46	20-27	1.50-1.60	0.6- 2.0	0.16-0.21	6.1-7.8	0- 2	LOW	.37			-
		46-60	10-15	1.40-1.70	0.2- 0.6	0.13-0.18	6.1-7.8	0- 2	LOW	.28			-
HrD	HARPT	0-10	12-22	1.50-1.60	0.6- 2.0	0.16-0.18	6.1-7.3	0- 2	LOW	.32	5	5	1.- 2.
		10-46	20-27	1.50-1.60	0.6- 2.0	0.16-0.21	6.1-7.8	0- 2	LOW	.37			-
		46-60	10-15	1.40-1.70	0.2- 0.6	0.13-0.18	6.1-7.8	0- 2	LOW	.28			-
HrE	HARPT	0-10	12-22	1.50-1.60	0.6- 2.0	0.16-0.18	6.1-7.3	0- 2	LOW	.32	5	5	1.- 2.
		10-46	20-27	1.50-1.60	0.6- 2.0	0.16-0.21	6.1-7.8	0- 2	LOW	.37			-
		46-60	10-15	1.40-1.70	0.2- 0.6	0.13-0.18	6.1-7.8	0- 2	LOW	.28			-
HwB	HAW	0-12	10-20	1.25-1.35	0.6- 2.0	0.16-0.21	6.1-7.8	-	LOW	.43	4	5	2.- 4.
		12-18	10-20	1.30-1.40	0.6- 2.0	0.16-0.21	6.1-7.8	-	LOW	.43			-
		18-30	22-34	1.30-1.45	0.2- 0.6	0.14-0.21	6.1-7.8	-	MODER	.37			-
		30-49	10-25	1.35-1.45	6.0- 20	0.11-0.18	7.4-9.0	0- 2	LOW	.28			-
		49-60	2- 7	1.55-1.70	20- 20.0	0.03-0.08	7.4-9.0	0- 2	LOW	.15			-
HwC	HAW	0-12	10-20	1.25-1.35	0.6- 2.0	0.16-0.21	6.1-7.8	-	LOW	.43	4	5	2.- 4.
		12-18	10-20	1.30-1.40	0.6- 2.0	0.16-0.21	6.1-7.8	-	LOW	.43			-
		18-30	22-34	1.30-1.45	0.2- 0.6	0.14-0.21	6.1-7.8	-	MODER	.37			-
		30-49	10-25	1.35-1.45	6.0- 20	0.11-0.18	7.4-9.0	0- 2	LOW	.28			-
		49-60	2- 7	1.55-1.70	20- 20.0	0.03-0.08	7.4-9.0	0- 2	LOW	.15			-
[illegible]	HAW	0-12	10-20	1.25-1.35	0.6- 2.0	0.16-0.21	6.1-7.8	-	LOW	.43	4	5	2.- 4.

ENGINEERING INDEX PROPERTIES
TABLE 1

Survey Area- GEM COUNTY AREA, IDAHO

Map Symbol	Soil Name	Depth (In)	USDA Texture	Classification Unified	Classification AASHTO
		11-15	UWB		
GtE	GWIN	0- 5	STV-L	GM GM-GC	A-4
		5-16	CBV-SICL CBX-SICL GRX-CL	GC	A-2 A-6
		16-20	UWB		
GwE	GWIN	0- 5	STX-L	GM	A-2 A-4
		5-16	CBV-SICL CBX-SICL GRX-CL	GC	A-2 A-6
		16-20	UWB		
GwF	GWIN	0- 5	STX-L	GM	A-2 A-4
		5-16	CBV-SICL CBX-SICL GRX-CL	GC	A-2 A-6
		16-20	UWB		
GwG	GWIN	0- 5	STX-L	GM	A-2 A-4
		5-16	CBV-SICL CBX-SICL GRX-CL	GC	A-2 A-6
		16-20	UWB		
HaB	HARPT	0-10	COSL	SM	A-2 A-4
		10-46	SIL L FSL	CL-ML CL SC SM-SC	A-4 A-6
		46-60	SR- COSL CL	SM ML	A-4
HaC	HARPT	0-10	COSL	SM	A-2 A-4
		10-46	SIL L FSL	CL-ML CL SC SM-SC	A-4 A-6
		46-60	SR- COSL CL	SM ML	A-4
HaD	HARPT	0-10	COSL	SM	A-2 A-4
		10-46	SIL L FSL	CL-ML CL SC SM-SC	A-4 A-6
		46-60	SR- COSL CL	SM ML	A-4
HaE	HARPT	0-10	COSL	SM	A-2 A-4
		10-46	SIL L FSL	CL-ML CL SC SM-SC	A-4 A-6
		46-60	SR- COSL CL	SM ML	A-4
HrA	HARPT	0-10	L	CL-ML	A-4
		10-46	SIL L FSL	CL-ML CL SC SM-SC	A-4 A-6
		46-60	SR- COSL CL	SM ML	A-4
HrB	HARPT	0-10	L	CL-ML	A-4
		10-46	SIL L FSL	CL-ML CL SC SM-SC	A-4 A-6
		46-60	SR- COSL CL	SM ML	A-4
HrC	HARPT	0-10	L	CL-ML	A-4
		10-46	SIL L FSL	CL-ML CL SC SM-SC	A-4 A-6
		46-60	SR- COSL CL	SM ML	A-4
HrD	HARPT	0-10	L	CL-ML	A-4
		10-46	SIL L FSL	CL-ML CL SC SM-SC	A-4 A-6
		46-60	SR- COSL CL	SM ML	A-4
HrE	HARPT	0-10	L	CL-ML	A-4
		10-46	SIL L FSL	CL-ML CL SC SM-SC	A-4 A-6
		46-60	SR- COSL CL	SM ML	A-4
HwB	HAW	0-12	L	ML CL-ML	A-4
		12-18	L SIL	ML CL-ML	A-4
		18-30	CL SCL L	CL SC	A-6
		30-49	COSL L SL	SM ML SC CL	A-2 A-4 A-6

APPENDIX F

Irrigation Flow Rate Questionnaire

IRRIGATION FLOW RATE QUESTIONNAIRE

The information required in this questionnaire will describe your water delivery system and irrigation methods. This information is essential in order for IDWR staff to evaluate your irrigation water requirements. Much of the information is technical, and you may wish to contact your County Extension Agent, the Natural Resources Conservation Service (formerly SCS) or other professionals for assistance with this form.

1. Please provide your name, address, and phone number where you may be contacted for further information or clarification. Include the claim number(s) for those claims where the irrigation flow rate is greater than 0.02 cfs (1 miner's inch) per acre.

Name ____________________

Address ____________________

Phone ____________________

Claim No(s). ____________________

2. Provide the total number of acres irrigated ________ for the claims listed.

3. Provide a detailed diagram or copy of an aerial photograph showing the complete irrigation system for the claims listed. Please include the location of wells, pipelines, canals or ditches, field headgates, and individual field boundaries. Please label by name (or identify by number) each of the elements shown.

4. Provide a description of the water conveyance system from the source to the farm and any major on-ᵣm laterals. This information should include: general soil type (for earthen ditches or canals), type of ᵤning (for lined ditches or canals), length of canal, width of canal at water surface, total depth from land surface to bottom of canal. Use average values. Also include any pipeline lengths and diameters.

this conveyance system shared by other water users? __________ If yes, please describe.

Is the water supply for the claims listed rotated with other water users? ___________ If yes, please describe.

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5. **For each field**, please provide the following information (this page may be copied for each individual field if necessary):

field name or identifying number ____________ type of irrigation system ________________

historical crop rotation ____________________ number of acres irrigated ________________

Provide the following information, for each field, based on the **peak water-use period** for the **highest water-use crop** historically grown.

crop type requiring highest flow rate ______________

number of days to irrigate entire field ______________ irrigation set time (hrs) ____________

irrigation frequency ______ (number of days from the start of one irrigation cycle to the start of the next for a given field)

Please draw a diagram of each field showing general shape and dimensions, include the following information:

<u>For sprinkler systems</u>

location of mainlines
number of laterals
spacing between sprinklers and laterals
nozzle size
average nozzle pressure
average nozzle flow

<u>For surface systems</u>
(furrow, corrugation, border, wild flood, etc.)

field length
direction of flow
slope of field in direction of flow
spacing between furrows, borders, etc.

6. Are you aware of any irrigation system design, evaluations or farm soil surveys completed for this ırm by the Natural Resources Conservation Service, private consultants, irrigation equipment dealers or others?

If yes, please describe or attach copies.

7. Please include any additional comments which will aid in the evaluation of your irrigation water requirements.

IDWR may rely on the information in this questionnaire for recommendation of your water right to the SRBA District Court. In order to minimize objections to IDWR's recommendation of your water right, ıease be sure that all information provided is as accurate as possible.

I certify that the information provided in this questionnaire is accurate and true to the best of my knowledge and belief.

______________________ signature ________ date

PLEASE RETURN FORMS TO:

APPENDIX G

NRCS Border Program
Sample Output

GRADED BORDER EVALUATION

name:
By:

Location:
Date: Jun 25, 1996

Roughness coefficient (n)= 0.250
Slope (S)= 0.0100 ft/ft
Net application (Fn)= 2.50 inches
Inflow time (Ti)= 8 hours, 0 minutes

Intake family (If)=3.00
Border width (W)= 40 ft
Border length (L)= 600 ft

Flow per Border (cfs)	Unit Flow (cfs/ft)	Gross Application (in)	Deep Percolation (in)	Runoff (in)	Application Efficiency (percent)	Notes
1.50	Gross depth is less than required gross application depth					
1.51	Gross depth is less than required gross application depth					
1.52	Gross depth is less than required gross application depth					
1.53	Gross depth is less than required gross application depth					
1.54	Gross depth is less than required gross application depth					
1.55	Gross depth is less than required gross application depth					
1.56	Gross depth is less than required gross application depth					
1.57	0.039	22.61	20.08	0.03	11.1	
1.58	0.040	22.75	20.08	0.17	11.0	
1.59	0.040	22.90	20.08	0.32	10.9	
1.60	0.040	23.04	20.08	0.46	10.9	

GRADED BORDER EVALUATION

Job name:
By:

Location:
Date: Jun 25, 1996

Roughness coefficient (n)= 0.250
Slope (S)= 0.0100 ft/ft
Net application (Fn)= 2.50 inches
Inflow time (Ti)= 4 hours, 0 minutes

Intake family (If)=3.00
Border width (W)= 40 ft
Border length (L)= 600 ft

Flow per Border (cfs)	Unit Flow (cfs/ft)	Gross Application (in)	Deep Percolation (in)	Runoff (in)	Application Efficiency (percent)	Notes
1.75	Gross depth is less than required gross application depth					
1.76	Gross depth is less than required gross application depth					
1.77	Gross depth is less than required gross application depth					
1.78	Gross depth is less than required gross application depth					
1.79	Gross depth is less than required gross application depth					
1.80	0.045	12.96	10.46	0.00	19.3	
1.81	0.045	13.03	10.46	0.08	19.2	
1.82	0.045	13.10	10.46	0.15	19.1	
1.83	0.046	13.18	10.46	0.22	19.0	
1.84	0.046	13.25	10.46	0.29	18.9	
1.85	0.046	13.32	10.46	0.36	18.8	

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GRADED BORDER EVALUATION

J name:
By:

Location:
Date: Jun 25, 1996

Roughness coefficient (n)= 0.250
Slope (S)= 0.0100 ft/ft
Net application (Fn)= 2.50 inches
Inflow time (Ti)= 2 hours, 0 minutes

Intake family (If)=3.00
Border width (W)= 40 ft
Border length (L)= 600 ft

Flow per Border (cfs)	Unit Flow (cfs/ft)	Gross Application (in)	Deep Percolation (in)	Runoff (in)	Application Efficiency (percent)	Notes
2.05	Gross depth is less than required gross application depth					
2.06	Gross depth is less than required gross application depth					
2.07	Gross depth is less than required gross application depth					
2.08	Gross depth is less than required gross application depth					
2.09	0.052	7.52	5.00	0.03	33.2	
2.10	0.052	7.56	5.00	0.06	33.1	
2.11	0.053	7.60	5.00	0.10	32.9	
2.12	0.053	7.63	5.00	0.14	32.8	
2.13	0.053	7.67	5.00	0.17	32.6	
2.14	0.053	7.70	5.00	0.21	32.5	
2.15	0.054	7.74	5.00	0.24	32.3	

GRADED BORDER EVALUATION

Job name:
By:

Location:
Date: Jun 25, 1996

Roughness coefficient (n)= 0.250
Slope (S)= 0.0100 ft/ft
Net application (Fn)= 2.50 inches
Inflow time (Ti)= 1 hours, 0 minutes

Intake family (If)=3.00
Border width (W)= 40 ft
Border length (L)= 600 ft

Flow per Border (cfs)	Unit Flow (cfs/ft)	Gross Application (in)	Deep Percolation (in)	Runoff (in)	Application Efficiency (percent)	Notes
2.40	Gross depth is less than required gross application depth					
2.41	Gross depth is less than required gross application depth					
2.42	Gross depth is less than required gross application depth					
2.43	Gross depth is less than required gross application depth					
2.44	Gross depth is less than required gross application depth					
2.45	0.061	4.41	1.90	0.01	56.7	(2)
2.46	0.061	4.43	1.90	0.03	56.5	(2)
2.47	0.062	4.45	1.90	0.05	56.2	(2)
2.48	0.062	4.46	1.90	0.06	56.0	(2)
2.49	0.062	4.48	1.90	0.08	55.8	(2)
2.50	0.062	4.50	1.90	0.10	55.6	(2)

(2) Erosive stream-- non-sod forming crops.

APPENDIX H

IDWR Adjudication Memorandum #43

ADJUDICATION MEMO # 43

To: Adjudication Staff
From: Jeff Peppersack
Date: July 27, 1995

Approved: NCY NCY
DBS DBS

Re: Irrigation Diversion Rate Calculations - Weighted Averages

This memo is notification of a change in our standard procedure to calculate irrigation diversion rates as described in the EVALUATION WORKBOOK FOR IRRIGATION DIVERSION RATES by Hubble Engineering, Inc. and Associated Earth Sciences Inc. This change will affect the calculation procedure described for Table 1 of the report.

Table 1 requires calculation of a weighted average for efficiency and net irrigation requirement based on acreages of each crop. These "summary" values are used in the next step which requires selection of the largest summary monthly value of net irrigation requirement to divide by the summary efficiency which results in the field requirement.

The change to this procedure is described as follows: After entering each crop's net irrigation requirement for each month (see Adjudication Memo #42), divide by the efficiency of the individual system for each crop. The result will be the crop's peak field requirement or the gross application amount for each month. Next, calculate a weighted average (based on crop acreages) of the gross application amount for each month. Select the largest summary value of gross application amount and convert to cfs/acre as described in the Hubble workbook.

A new spreadsheet has been developed to aid in the calculations required for Table 1 of the Hubble workbook (see example attached). This spreadsheet also incorporates the changes to the Hubble methodology described in Adjudication Memo #42. Average irrigation requirement values can be entered directly from the Allen and Brockway tables. Peak consumptive irrigation requirement values will be calculated automatically in the spreadsheet.

Please discontinue using all past spreadsheets using the old methodology. Copies of the new spreadsheet can be obtained from Jeff Peppersack.

FIELD IRRIGATION REQUIREMENT

Initials: JP Claimant = xx

date: 07/27/95 Weather Station = Emmett

				Net Irrigation Requirement (monthly ave. in mm/day)												Gross Irrigation Application (peak cir/eff. in mm/day)								
crop	acres	irrig. system	eff. (%)	mar	apr	may	jun	jul	aug	sep	oct	season (mm/yr)	irrig. app. (in)	cir ratio	irrig. freq. (days)	mar	apr	may	jun	jul	aug	sep	oct	season (mm/yr)
alfh	120	cer	30		3.1	5.25	6.25	6.99	5.27	3.49	0.78	950	2.70	1.10	8.9		11.37	19.25	22.92	25.63	19.32	12.80	2.86	3167
alfh	160	spr	65		3.1	5.25	6.25	6.99	5.27	3.49	0.78	950	2.70	1.10	8.9		5.25	8.88	10.58	11.83	8.92	5.91	1.32	1462
sweet	40	fur	35		0.96	1.46	3.67	8.45	6.82	4.39	1.55	835	2.10	1.11	5.7		3.04	4.63	11.64	26.80	21.63	13.92	4.92	2386
Summary	320																7.27	12.24	15.34	18.88	14.41	9.49	2.35	2216

Peak Gross Irrigation Application (mm/day) = 18.88
Irrigation Diversion Requirement (cfs/acre) = 0.031
Total Irrigation Diversion Requirement (cfs) = 9.99
Irrigation Diversion Volume (ft/yr) = 7.27
Total Irrigation Diversion Volume (ac-ft/yr) = 2327

SNAKE RIVER ASSOCIATION

FIELD IRRIGATION REQUIREMENT

TECH: ______ DATE: ______
WEATHER STATION: ______ CLAIMANT: ______ ID NO. ______

CROP	ACREAGE ACRES	ACREAGE %	TYP IRR	IRR EFF %	MAR MM/DAY	APR MM/DAY	MAY MM/DAY	JUN MM/DAY	JUL MM/DAY	AUG MM/DAY	SEP MM/DAY	OCT MM/DAY	SEASON MM/SEA
ALFH.	120	38	COR	30		3.10	5.25	6.25	6.99	5.27	3.49	0.78	950
ALFH.	160	50	SPR	65		3.10	5.25	6.25	6.99	5.27	3.49	0.78	950
SBEET	40	13	FUR	35		0.96	1.46	3.67	8.45	6.82	4.39	1.55	835
SUMMARY	320	100		48		2.83	4.78	5.94	7.17	5.46	3.60	0.88	936

PROCEDURE IN WORKBOOK

7.17 / 0.48 × 0.001657 = 0.0248 CFS/AC   0.0248 CFS/AC × 320 AC = 7.92 CFS

ADDING THE REQUIREMENTS FOR EACH INDIVIDUAL FIELD:

ALFH 6.99 / 0.30 × 0.001657 = 0.0386 CFS/AC   0.0386 CFS/AC × 120 AC = 4.63 CFS

ALFH 6.99 / 0.65 × 0.001657 = 0.0178 CFS/AC   0.0178 CFS/AC × 160 AC = 2.85 CFS

SBEET 8.45 / 0.35 × 0.001657 = 0.040 CFS/AC   0.040 CFS/AC × 40 AC = 1.60 CFS

9.08 CFS

CORRECT WEIGHTING WOULD BE AS FOLLOWS: 0.0284 CFS/AC × 320 = 9.08 CFS

ALFH 6.99 / 0.30 × 120/320 = 8.74 mm/day

ALFH 6.99 / 0.65 × 160/320 = 5.38 mm/day

SBEET 8.45 / 0.35 × 40/320 = 3.02 mm/day

SUMMARY 17.14 mm/day × 0.001657 = 0.0284 CFS/AC

LARGEST SUMMARY MONTHLY VALUE ______, DIVIDE BY SUMMARY IRR. EFF. = ______ MM/DAY, MULTIPLY BY 0.001657 = ______ CFS/ACRE FIELD REQUIREMENT, ADD FARM DELIVERY LOSS ______ CFS/AC. = ______ CFS/AC MULTIPLY BY SUMMARY ACRES = ______ CFS FIELD REQUIREMENT ADD CONVEYANCE LOSS OF ______ CFS ______ CFS DIVERSION REQUIREMENT. DIVIDE BY SUMMARY ACRES TO CHECK CFS/ACRE = ______ AT THE POINT

TABLE

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APPENDIX I

Payette Seepage Study

STATE OF IDAHO
DEPARTMENT OF WATER RESOURCES

Cecil D. Andrus
Governor

R. Keith Higginson
Director

Statehouse
Boise, Idaho 83720
(208) 384-2215

December 3, 1975

MEMORANDUM

TO: Gary Page

FROM: John Bessaw

SUBJECT: Payette Seepage Study

Due to the many miles of canal in the Payette drainage, it was decided that it would be impractical to try to measure the actual seepage losses. It was felt that less direct approach would be better. This was to measure the actual losses through a selected reach of canal and compare the values obtained with those calculated from existing formulas, derived from previous seepage studies. After it was seen how the two values compared, it appears the use of the equations would be a better way to obtain a seepage value for the entire system of canals.

Four formulas were found for estimating seepage loss in canals. Two formulas, Moritz and Etcheverry would require that a large amount of additional field work be done. They are based on flow and velocity in addition to the soil seepage rate. The Etcheverry formula would also require additional information on the side slope and bottom width of the canal.

Two other formulas were found. These were somewhat simpler in form and would only require a top width measurement and a value for the soil seepage rate. One was developed by Robert Worstell in reviewing past seepage studies and combined with work he performed on seepage in Idaho. The other was one used by Brent A. Claiborn in a masters thesis studying irrigation efficiencies in the upper Snake River.

Values from all four equations were compared against values obtained from an inflow-outflow test on the Emmett Irrigation District north side canal. The test was conducted at the end of the season to reduce the number of inflow-outflow measurements that would be required, since all the farm headgates could be closed off.

Two reaches were selected, both on the main canal. The upper reach was from the end of the flume near the point of diversion to the siphon at Bissel Creek. This canal ran along the sidehill through mostly sandy

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soil. It was boarded up to maintain the water surface at approximately normal operation level. The second reach was on the lower end of the main canal from the siphon to Sand Hollow. This section of canal also ran along the hillside and passed through sandy soils.

The results obtained from the actual inflow-outflow tests were compared to the values calculated from the four equations. The following two tables show the different values obtained from both the upper and lower end of the Emmett Irrigation District's Main Canal.

TABLE I

SEEPAGE LOSSES
UPPER END

	Loss cfs/mile
Measured loss	3.1
Moritz	1.4 to 2.8
Etcheverry	1.2 to 2.4
Worstell	1.4 to 2.9
Claiborn	1.5 to 3.0

The range of values was obtained from using different soil seepage rates. From an onsite inspection and the use of soil maps the soil seepage rate was estimated and range from 1.0-2.0 feet/day for the upper reach and .5 to 1.5 feet/day on the lower reach of the canal.

TABLE II

SEEPAGE LOSSES
LOWER END

	Loss cfs/mile
Measured loss	1.3
Moritz	.5 to 1.5
Etcheverry	.4 to 1.2
Worstell	.6 to 1.7
Claiborn	.6 to 1.9

The results obtained from the different equations were quite similar to those measured, especially in the upper reach in most cases. It seemed that the higher soil seepage rates gave the best comparison with actual measured losses. It would appear from this limited test that no matter which equation was used that final results would be approximately the same.

The measured loss in the lower reach didn't compare quite as well to those obtained from the equations. This could partly be due to the fact that the water surface in the lower reach could not be maintained as close to the normal operation level as it was in the upper reach.

There are some limitations to the field measurements that were taken. Due to the amount of time and money available, only one set of measurements could be made and are estimated to be within + 5%. Another limitation is that the measurements were taken at the end of the season. This could tend to reduce the losses since the soil around the canal would be saturated and the bottom would tend to seal off from silt.

There also could be some question to how well the reaches selected would represent other canals in the drainage. Since both were along the hillside and passed through sandy soils, this could represent higher than average losses.

To use either of the simpler forms of the equations to calculate seepage losses, some additional information is going to be required. Measurements of the canal or lateral top width along with the length of each canal would be required. The department does have a computer program that calculates the seepage loss using the equation developed by Claiborn. It is presently set up to use measurements from SCS aerial photos, 8" = 1 mile but could be changed to use data already collected or from other sources.

Additional information would be required on the canal systems operation if an acre foot value is going to be calculated for the entire season. The formulas alone will only give an estimate of the loss in cfs/mile during the periods when the canals are flowing full.

JB:nc